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ABSTRACT

The proceedings of a meeting which focused on topics and issues related to the pipeline for scientists and engineers are presented. They include the meeting agenda, introductory comments, an overview, summaries of five presentations, the meeting summary, and a list of participants. The overview (by Betty Vetter) outlines some ways of measuring the potential supply of new scientists and engineers. The five papers are: (1) "The Underrepresentation of Women and Minorities in Quantitative Fields: How Does It Occur?" (by Sue Berryman), in which findings from the author's report "Who Will Do Science?" are discussed; (2) "The Post-Secondary Pipeline and Supply/Utilization Aspects of the Labor Market for Scientists and Engineers" (by Charles Falk), which includes 23 charts with data on this topic collected by the National Science Foundation; (3) "Prospects for the Future Talent Pool of Physicists" (by Beverly Porter), which reviews some of the trends of the past decades; (4) "The Talent Pool for Engineering: Are the Colleges the Only Source?" (by Alan Fechter), which examines the talent pool for engineering and examines the various sources from which this talent is drawn; and (5) "Continuing Education for Scientists and Engineers" (by Anthony Carnevale), which emphasizes the need for education, training, and retraining. Roger Wilcox presided over the summary and "Wrap-Up." (JN)

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THE SCIENCE AND ENGINEERING TALENT POOL

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PROCEEDINGS

of the

1984 Joint Meeting of the Scientific Manpower Commission and the Engineering Manpower Commission

NATIONAL ACADEMY OF SCIENCES
Washington, DC

May 15, 1984

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THE SCIENCE AND ENGINEERING TALENT POOL

Components, Quality, and Access. Prospects for the Future

The 1984 Joint Meeting of the Scientific Manpower Commission and the Engineering Manpower Commission

WHEN? 9:00 a.m. to 1:00 p.m., Tuesday, May 15, 1984*

WHERE? The Lecture Room, Main Building, National Academy of Sciences
2101 Constitution Avenue, Washington, D.C.

Agenda

9:00 a.m.	Introductions and Overview *Betty Vetter, Executive Director, Scientific Manpower Commission* *Bill G. Aldridge, Vice President, Scientific Manpower Commission* *(Executive Director, National Science Teachers Association)*
9:30	The Underrepresentation of Women and Minorities in Quantitative Fields: How Does It Occur? *Sue Berryman, The Rand Corporation, Washington, D.C.*
10:15	Coffee Break
10:30	The Post-Secondary Pipeline and Supply/Utilization Aspects of the Labor Market for Scientists and Engineers *Charles E. Falk, Director, Division of Science Resources Studies, National Science Foundation*
10:50	Prospects for the Future Talent Pool of Physicists *Beverly Porter, American Institute of Physics, New York*
11:10	The Talent Pool for Engineering: Are the Colleges the Only Source? *Alan Fechter, National Research Council*
11:30	Continuing Education for Scientists and Engineers *Anthony Carnevale, Consulting Economist*
11:50	Summary and "Wrap-up" *Richard Wilcox, Center for Strategic and International Studies, Georgetown University*
12:00 p.m.	Audience Comments and Questions for Panelists *Moderator: Bill G. Aldridge*
1:00	Adjourn

*There will be a working luncheon for EMC and SMC members from 1:00 p.m.–2:30 p.m.

PROCEEDINGS

JOINT MEETING OF THE SCIENTIFIC MANPOWER COMMISSION AND THE ENGINEERING MANPOWER COMMISSION

National Academy of Sciences, Lecture Room, 2101 Constitution Ave., N.W., Washington, D.C.

May 15, 1984

The meeting was called to order by SMC President, **Joy Stapp**, who welcomed members of the two Commissions and invited guests.

Bill Aldridge, SMC Vice President and Executive Director of the National Science Teachers Association, introduced the topic for the day - **The Pipeline for Scientists and Engineers.**

Not for years has such a collection of data been brought together on the pipeline issue. The 18-24 year old population will drop from 29.4 million in 1981 to below 26 million in 1988, and this drop coincides with a period of increasing demand for well educated specialists.

Based on the age of today's science teachers, there will be a large outflow of retirees in 1992, coinciding with a large influx of new students now in an increasing group of pre-schoolers. Since both the quality and quantity of new scientists and engineers produced over the next two decades is based in significant measure on the quality and quantity of pre-college science teachers and teaching, we will examine various aspects of the pipeline, beginning with the pre-school populations.

SMC Executive Director, **Betty Vetter**, outlined some ways of measuring the potential supply of new scientists and engineers. Her paper follows:

Ignoring for the moment immigrants and transfers into these fields, the supply is based first of all on population demographics. If we assume that students will make choices for science or engineering in approximately the same proportion over the next decade as they did over the last, we can measure the supply by just taking a percentage of the age group for any period. If we think this won't yield enough graduates, we can increase the proportion somewhat by providing such incentives as scholarships or fellowships for study in particular fields. We also depend on students to tend toward fields where the present job market for graduates is good. Unfortunately, such students are looking at that marketplace four to eight years before they can affect or be affected by it, but if drastic changes do not occur, their choices work out alright.

We should look at the potential pool from which tomorrow's technological specialists will be derived, in order to find out whether our present levels of production can be maintained, and whether that is likely to result in producing enough new entrants for demand. Looking ahead to the next 15 years, some facts are not in question.

The number of 22-year-olds will drop 26% between 1983 and 1999. This year's and next year's college graduating classes will be the largest in history, and 25% larger than the class of 1998. (fig. 1)

But the group I'd like to look at is the seventh grade level. I choose this year because seventh grade is the first time students have some choices in the courses they take.

The number of 13 year olds started dropping in 1973 and will reach its lowest point in 1988. This smallest group of seventh graders will not graduate from college until 1998, but the age group will also be relatively small for five years on either side of 1998. Let's follow that seventh grade through their years of education. We must assume that they will act in most ways like the generation ahead of them. (fig. 2)

Over the past 20 years, a fairly steady 3% of seventh graders ultimately earned a bachelor's degree in one of the quantitative fields - physical and biological sciences, math and computer science, engineering or economics. Assuming no change in rates, as the size of the seventh grade population drops, the size of the baccalaureate class a decade later also will drop, as will the number of graduates in quantitative fields.

Many of the quantitative fields require graduate degrees for professional activity so let's follow these seventh graders on through to the Ph.D. Because boys and girls tend to choose differently, I have divided them by sex. The percentages inside the boxes are the proportions of the original seventh grade boys and girls at each educational level who are still in our potential science/engineering manpower pool at that level. The percentages shown by the arrows designate the proportion of all students from our seventh grade group who move on to the next educational level.

Let's take an example, starting with a class of 4,000 seventh graders, half boys and half girls.

For every 2,000 seventh grade boys, 1,440 will graduate from high school, 900 will enter college, 480 will earn a bachelor's degree; 140 will earn a master's degree and 20 will earn a Ph.D. However, only about half of the children in the seventh grade class have understood, enjoyed, and can build on their mathematics education up to that time, so they make up our potential pool base at seventh grade for the quantitative fields. Let's follow that part of the class on through.

There are now 1,000 of these boys among our 4,000 seventh graders. But only 283 will finish high school with enough math background to go on in a quantitative field. Of this group, 143 will enter college with plans for a technical major, but only 44 will earn a first degree in a quantitative field. From these 44, 14 will go on to earn a master's degree and 5 a Ph.D. in a quantitative field. These proportions haven't changed more than a percentage point or two over the past 20 years, and we can't expect them to change much in the future.

Among our 2,000 seventh grade girls, 1,560 will graduate from high school, 830 will enter college, 440 will earn a bachelors degree, 150 a master's degree and 20 a Ph.D. However, only 1,000 are still in the potential pool of scientists and engineers at the seventh grade.

Despite their higher graduation rate, only a little more than one fifth of seventh grade girls will leave high school with the necessary course background to enter a quantitative field; 45 will enter college planning to major in science or engineering; 19 will earn a quantitative bachelor's degree, four a master's degree and one of the original 2,000 a Ph. D.

The elimination points are highest for both sexes during the high school years; so that only 28% of the boys and 22% of the girls have kept open the doors to a quantitative career by the time they graduate. Of course, all eligible students do not choose to go into these fields, so that only 14% of the senior boys and 4.5% of the girls indicate plans for a quantitative major in college.

The college years also eliminate many, so that only 4.4% of the boys and 1.9% of the original seventh grade girls actually earn a quantitative bachelor's degree. One in ten of the men earning a quantitative bachelor's degree will go on to a Ph. D., but only one in 20 of the women will go that far.

As you know, women have been entering and completing college in a far higher proportion over the past decade than at any time since the 1920's. But their relative choice of major fields has changed very little. Thus, although their numbers have increased, both among graduates and in the work force, the entire increase is based on their increase in college attendance and completion.

Similar flow charts for blacks and Hispanics show the same pattern of underutilization as we see here for women. If we want to increase the numbers of trained scientists and engineers who will emerge from the smaller school age population base, the intervention points are clear.

But whether we need more than will be produced under present assumptions, or whether we don't, we won't get the best we can get from that pool of potential seventh graders if we don't make better efforts to utilize more of them who happen to be girls, blacks, or Hispanics.

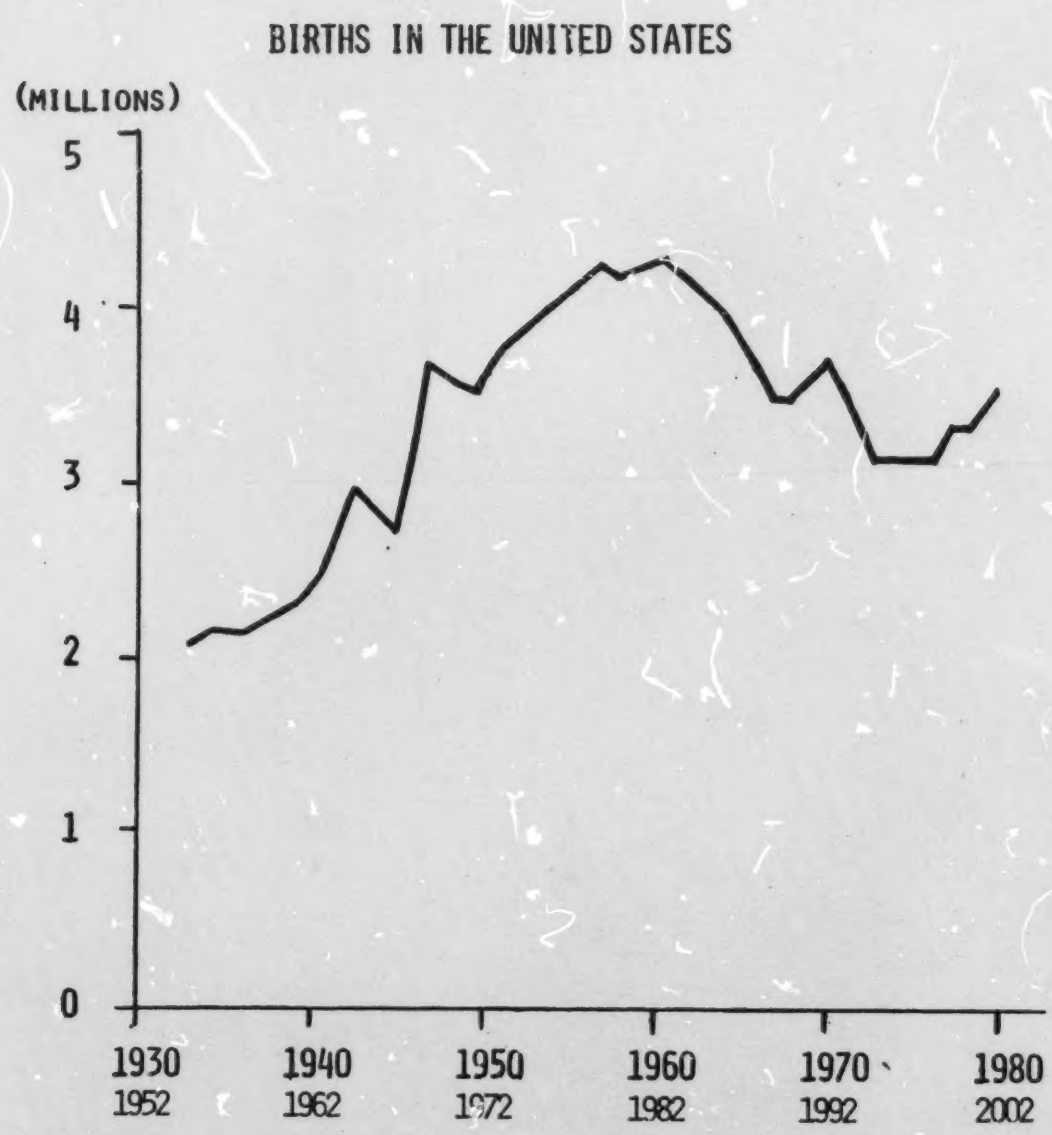

BIRTHS IN THE UNITED STATES
(MILLIONS)
5
4
3
2
1
0
1930
1940
1950
1960
1970
1980
1952
1962
1972
1982
1992
2002
(22-YEAR OLDS)
SOURCE: NATIONAL CENTER FOR HEALTH STATISTICS

Figure 1

THE POOL OF POTENTIAL SCIENTISTS AND ENGINEERS IN QUANTITATIVE FIELDS*

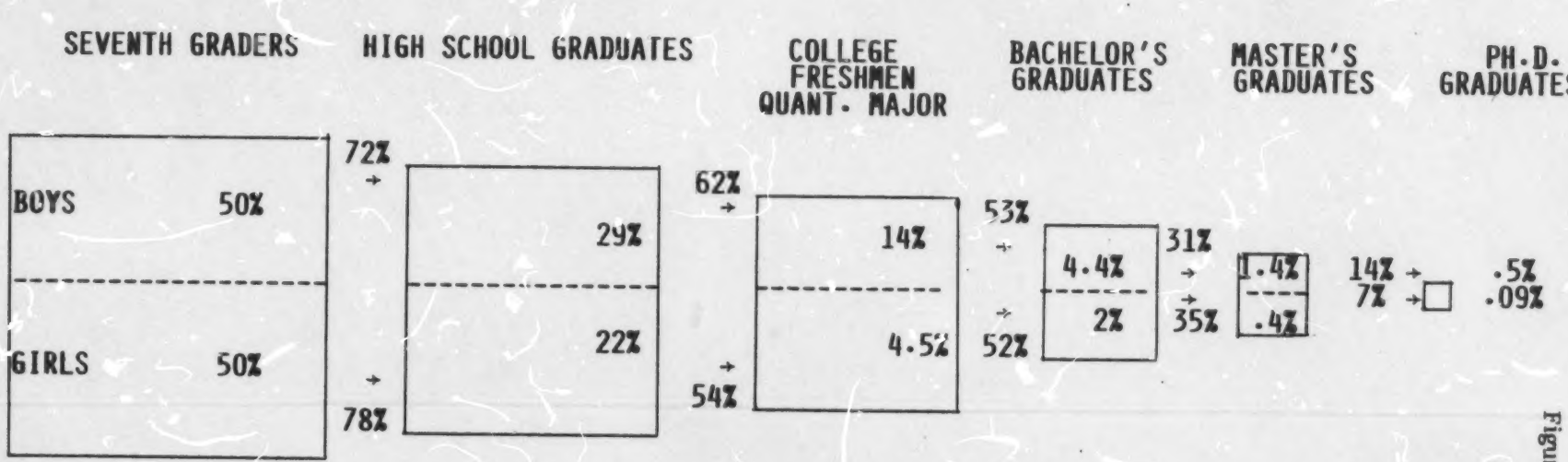


Figure 2

BOYS:												
STUDENTS	2000	→	1440	→	900	→	480	→	140	→	20
S/E POOL	1000	→	283	→	143	→	44	→	14	→	5
GIRLS:												
STUDENTS	2000	→	1560	→	830	→	440	→	150	→	10
S/E POOL	1000	→	217	→	45	→	19	→	4	→	1

*PHYSICAL SCIENCES, MATH SCIENCES, COMPUTER SCIENCES, BIOLOGICAL SCIENCES, ECONOMICS AND ENGINEERING

SOURCE: SCIENTIFIC MANPOWER COMMISSION

Sue Berryman of the Rand Corporation, and author of Who Will Do Science?, a special report published by the Rockefeller Foundation, discussed the findings in this report. A summary of her presentation follows.

The present representation of minorities and women among quantitative degree holders at all levels is shown in Tables 1-5. In comparison to whites, Asians are over-represented relative to their proportion in the population while blacks, Hispanics and American Indians are under-represented. Women are under-represented at all degree levels in quantitatively-based fields (Table 7).

In the labor force, these groups can be under-represented both because they are too sparse among graduates and because of higher attrition. Minorities are most disadvantaged by not having the required education; but their attrition rates are about average. For women, however, attrition is far higher.

Projecting forward, recent enrollment increases for minorities at undergraduate, graduate and professional levels are evident, but the enrollments at these levels in quantitative fields are not increasing significantly. The trends for women, both in total enrollment and in quantitative field enrollment, are quite positive, although women are still under-representated at the doctorate and professional degree levels.

The attrition losses are different at varying points for the minority groups. For women, the drop-off point at the Ph.D. is very large. Hispanics are under-represented at the bachelor's level. Although Hispanics show an increase in the proportion of both general and quantitative bachelor's degrees, in any given year, their share of the quantitative degrees is less than that of total degrees, and the gap between the two does not close across time. American Indians show steady shares of total and quantitative bachelor's degrees across time, while Asian-Americans show increases in both that exceed their increases in the age-relevant population. Although undergraduate enrollment data suggest that in the early 1980s blacks may show an increase in their B.A. shares beyond increases in their shares of the age-relevant population, the graduate enrollment data give no reason to expect much change in any subgroup's share of the graduate degrees.

How much does attrition from the educational pipeline, versus field choice, account for the representational status of these groups? To understand this completely, we need a better data base with cross sectional time series. However, for parts of the pipeline, we can estimate retention.

All subgroups lose members as the total population cohort progresses through the pipeline. However, the relative losses are not the same within each group.

- Non-Hispanic whites have greater persistence at each point in the pipeline except from the bachelor's to the master's degree.

- Blacks have less persistence at each state of the educational pipeline except from the B.A. to the M.A. degree, than do non-blacks.

- Hispanics have higher losses at each stage in the pipeline through college entry than do non-Hispanics. Once in college, they evidence lower or average losses.

- American Indians show very high losses between college entry and the bachelor's degree, but losses stabilize after the B.A.

- Asian Americans enter college in approximately equal proportion to their percent of 18 year olds, but their losses after college entry are lower at each stage of the educational pipeline than those of non-Asian Americans.

- Relative to men, women had stable lower losses at the high school graduation level during the 1970's, and their attrition subsequent to high school changed over time until they are now slightly over half of all bachelor's graduates. Losses from college entry to bachelor's degree were only slightly higher than for men, and have been stable across the decade. For most of the decade, losses from B.A. to M.A. were lower than men's, and increasingly lower as the decade progressed. However, attrition from B.A. to a professional degree and to the Ph.D. were higher than men's, but decreasingly so across the decade.

In field choice, however, differences between men and women and between minority groups show wider variation. Both women and all minority groups except Asian Americans are under-represented in the quantitative fields relative to their proportions in the population, although there are significant increases in the numbers and proportions of women in areas such as engineering.

The potential science manpower pool first emerges before 9th grade, and is essentially complete by 12th grade. After that time, migration is only outward. The major causes of women's under-representation in quantitative fields appear to be their math achievement after 9th grade, and their career preferences. Expectations of parents and of society differ between the sexes, and parents generally feel that girls must work harder than boys in mathematics. Additionally, preferences for quantitative careers affect the choices for math course taking. These same variables determine choice of majors. For women, career choices also reflect their desire for family-career combinations. So long as they see themselves as having the major responsibility of child rearing, they will tend to choose less time-demanding fields.

The problems of minorities within the educational pipeline are different. Socio-economic and cultural differences bring about variations in educational and career choices, and we do not understand those cultural differences.

Blacks and Hispanics start school with below average scores, and the pattern continues throughout the school years. Native Americans are below average on verbal scores, but average on mathematics. Asian Americans start school with above-average math scores, and below average verbal scores. There are clear reasoning differences among ethnic groups, and the socio-economic status also is highly related to academic choices and achievement.

The patterns of skill distribution among the minority groups remain throughout secondary school. Ethnic groups are more like each other than are socio-economic groups across cultures. Although the social class of the home affects achievement, cultural class differences persist regardless of socio-economic status. However, second-generation college attendance equalizes choices toward quantitative fields. Thus, changes over time in socio-economic status should result in changes in quantitative field choice.

SOURCE: Who Will Do Science, by Sue E. Berryman, The Rockefeller Foundation, November 1983

TABLE 1

1978/79 REPRESENTATION OF RACIAL AND ETHNIC GROUPS BY DEGREE LEVEL

Racial and Ethnic Group	Degree Level				
	Associate Degree	B.A.	M.A.	Ph.D.	Professional Degree
Total	100.0	100.0	100.0	100.0	100.0
Whites	82.3	88.1	88.5	90.8	91.2
Blacks	9.1	6.6	6.9	4.4	4.2
Hispanics	5.1	3.3	2.0	1.6	2.5
American Indians	0.6	0.4	0.4	0.4	0.3
Asian-Americans	1.9	1.7	2.0	2.8	1.8

TABLE 2

1978/79 REPRESENTATION RELATIVE TO REPRESENTATION IN THE AGE-RELEVANT POPULATION BY DEGREE LEVEL AND RACIAL AND ETHNIC GROUP

Racial and Ethnic Group	Degree Level				
	Associate Degree	B.A.	M.A.	Ph.D.	Professional Degree
Whites	1.04	1.11	1.10	1.11	1.14
Blacks	0.70	0.51	0.58	0.41	0.35
Hispanics	0.86	0.62	0.36	0.31	0.45
American Indians	0.86	0.57	0.66	0.66	0.50
Asian-Americans	1.27	1.13	1.05	1.33	0.95

SOURCE: Who Will Do Science, by Sue E. Berryman, The Rockefeller Foundation, November 1983

TABLE 3

1978/79 REPRESENTATION OF RACIAL AND ETHNIC GROUPS IN QUANTITATIVELY-BASED FIELDS* BY DEGREE LEVEL

Racial and Ethnic Group	Degree Level			
	B.A.	M.A.	Ph.D.	Professional Degree
Total	100.0	100.0	100.0	100.0
Whites	89.8	90.2	91.4	90.0
Blacks	4.1	2.5	1.7	4.1
Hispanics	2.9	1.6	1.1	2.6
American Indians	0.3	0.3	0.2	0.3
Asian-Americans	2.9	5.3	5.7	3.0

TABLE 4

1978/79 REPRESENTATION IN QUANTITATIVELY-BASED FIELDS* RELATIVE TO REPRESENTATION IN TOTAL DEGREES BY DEGREE LEVEL AND RACIAL AND ETHNIC GROUP

Racial and Ethnic Group	Degree Level			
	B.A.	M.A.	Ph.D.	Professional Degree
Whites	1.02	1.02	1.01	0.99
Blacks	0.62	0.36	0.39	0.98
Hispanics	0.88	0.80	0.69	1.04
American Indians	0.75	0.75	0.50	1.00
Asian-Americans	1.71	2.65	2.04	1.67

* Quantitatively-based fields for the B.A., M.A., and Ph.D. are defined to include the physical sciences, mathematics, computer sciences, biological sciences, engineering, and economics. For professional degrees the fields are biologically- or physically-based and defined to include medicine, dentistry, optometry, osteopathy, podiatry, veterinary medicine, and pharmacy.

SOURCE: Who Will Do Science, by Sue E. Berryman, The Rockefeller Foundation, November 1983

TABLE 5

1978/79 REPRESENTATION IN QUANTITATIVELY-BASED FIELDS* RELATIVE TO REPRESENTATION IN AGE-RELEVENT POPULATION BY DEGREE LEVEL AND RACIAL AND ETHNIC GROUP

Racial and Ethnic Group	Degree Level			
	B.A.	M.A.	Ph.D.	Professional Degree
Whites	1.13	1.12	1.12	1.12
Blacks	0.32	0.21	0.16	0.35
Hispanics	0.55	0.29	0.21	0.47
American Indians	0.43	0.50	0.33	0.50
Asian-Americans	1.93	2.79	2.71	1.58

TABLE 7

1978/79 PERCENT FEMALE IN QUANTITATIVELY-BASED FIELDS* BY DEGREE LEVEL

Degree Level	Percent Female in Quantitatively-Based Fields	Ratio of % Female in Quantitatively-Based Fields to % Female of Total Degrees	Ratio of % Female in Quantitatively-Based Fields to % Female of Age-Relevant Population
B.A.	25	0.51	0.50
M.A.	18	0.37	0.36
Ph.D.	15	0.50	0.30
Professional Degree	25	0.93	0.50

* Quantitatively-based fields for the B.A., M.A., and Ph.D. are defined to include the physical sciences, mathematics, computer sciences, biological sciences, engineering, and economics. For professional degrees the fields are biologically- or physically-based and defined to include medicine, dentistry, optometry, osteopathy, podiatry, veterinary medicine and pharmacy.

Dr. Charles Falk, Director of the Division of Science Resources Studies of the National Science Foundation, discussed the post-secondary pipeline and supply/utilization aspects of the labor market for scientists and engineers.

Flows into and out of the occupational labor market for science and engineering (chart 1) occur all the time. Starting with the existing S/E labor force, deletions include those who switch fields, die, retire or emigrate; additions include new graduates, re-entrants and immigrants. The NSF collects data on all of these groups except emigrants.

Beginning with the dynamic features of the model, the largest part of the change is the addition of new entrants, including new graduates, re-entrants, and immigrants. Forty percent of the 1978 total S/E pool consisted of individuals who had entered the system since 1970.

As indicated by the index of S/E degree production (chart 2), there was a drop in the number of doctorates awarded and an increase in bachelor's and master's degrees. The changes are distinctive in B.S. production by sex. The number of men graduating dropped in the social, life and math sciences, but grew in engineering, physical and computer sciences. The number of women increased in all fields except mathematics (chart 3). The overall increase from 1972-1982 was only 7.5%.

Degrees awarded differ by field. Computer sciences rose five-fold, with an accompanying decrease in math.

We have some information on the changes in the quality of S/E students, based on SAT and GRE scores from the Educational Testing Service. There have been no huge declines in GRE scores (chart 4), and perceptions of student quality by educational institutions confirm this, according to a recent ad hoc survey by NSF (chart 5). Indeed, the majority of institutions see a shift of the most able undergraduates toward science and engineering (chart 6).

The next phase for baccalaureates is the transfer from undergraduate school. About [illegible] enter graduate school, and 4% remain outside the labor force, while the remainder enters the labor force. Within this group, 94% are employed, but only 60% are employed in jobs related to science and engineering (chart 7).

NSF collects data on the numbers of graduate students by sex (chart 8), their support patterns, and other characteristics. For example, support patterns (chart 9) indicated that although the number of fellowships dropped 17% between 1967 and 1982, other sources have compensated.

We have very elaborate data on doctorates, collected by the National Academy of Sciences for NSF, NEH and NIH. Data on new doctorate awards also include the involvement of foreign students (charts 10 and 11). Following a long plateau in number of doctorate awards, both the total and the number of foreign citizen awards are starting up again.

Between 1978 and 1983, total S/E Ph.D. production has increased in all fields except the social sciences, with the largest increase in engineering (Chart 12). However the involvement of foreign students, which varies by field, requires care in interpretation of the degree production figures. Engineering has the largest representation of foreign students - 53%. The foreign students in engineering (chart 13) include both permanent residents and temporary residents, and the divisions should be noted in interpreting the data.

The pull of the market for baccalaureate engineers has removed U.S. students from the doctoral student population.

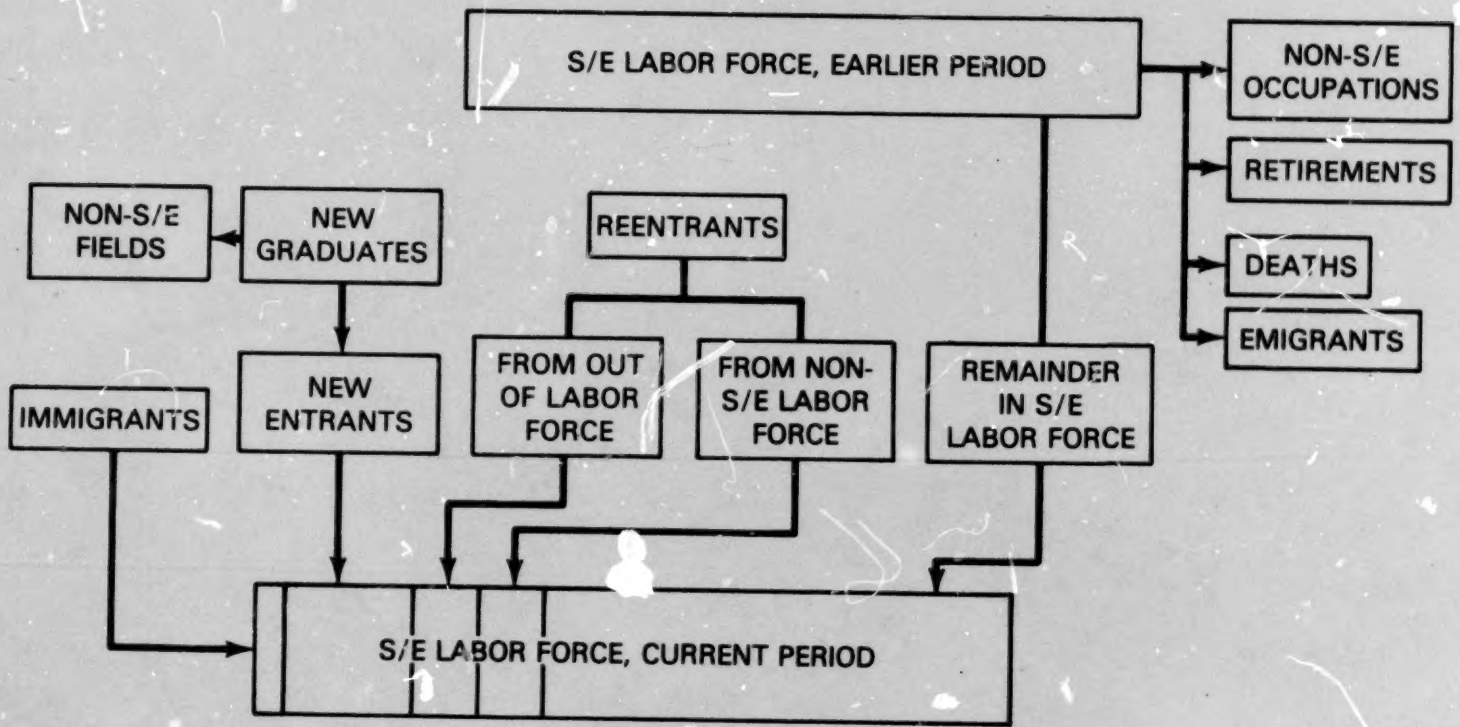
NSF also has data on S/E faculty. One source of concern is the decreasing proportion of S/E faculty members who are recent graduates, dropping from 39% in 1968 to 28% in 1974 and 21% in 1980 (chart 14). Faculty information includes also how faculty members spend their professional time, age distribution of faculty, etc. Institutional data include characteristics of postdoctorates, detailed information on R&D expenditures by field and source, federal obligations by agency, field and type of support for every school. NSF can provide profiles for every institution.

Eventually, scientists and engineers do move out of the educational part of the pipeline and into the utilization aspects of the labor force. For this group, NSF measures numerous characteristics as indicated in chart 15. Three major data bases provide information on distribution by field and employment sector, over time (chart 16); distribution by field and primary work activity (chart 17), and occupational patterns. Field distribution differs by sex, with more men engineers and more women social or life scientists (charts 18 and 19). The representation of minorities in S/E fields also is determined.

An annual survey of employers tries to determine relative changes in the supply/utilization balance by asking for employer perceptions of shortage fields. A large change occurred between 1981 and 1983 (charts 20 and 21) with many employers reporting shortages in several fields in 1981, the number dropping in 1982 and being very low in 1983. Even in the fields of computer science, geology, chemistry and math, where shortages were reported in 1981, no shortages were reported by 1983. The lesson is not to react to short term problems caused by economic cycles.

This has been a rapid over-view of the available data on the S/E population. Compared with data available in other countries, the breadth of U.S. data is impressive. Charts 22 and 23 summarize the available data cells.

SCIENCE/ENGINEERING (S/E) OCCUPATIONAL LABOR-MARKET FLOWS



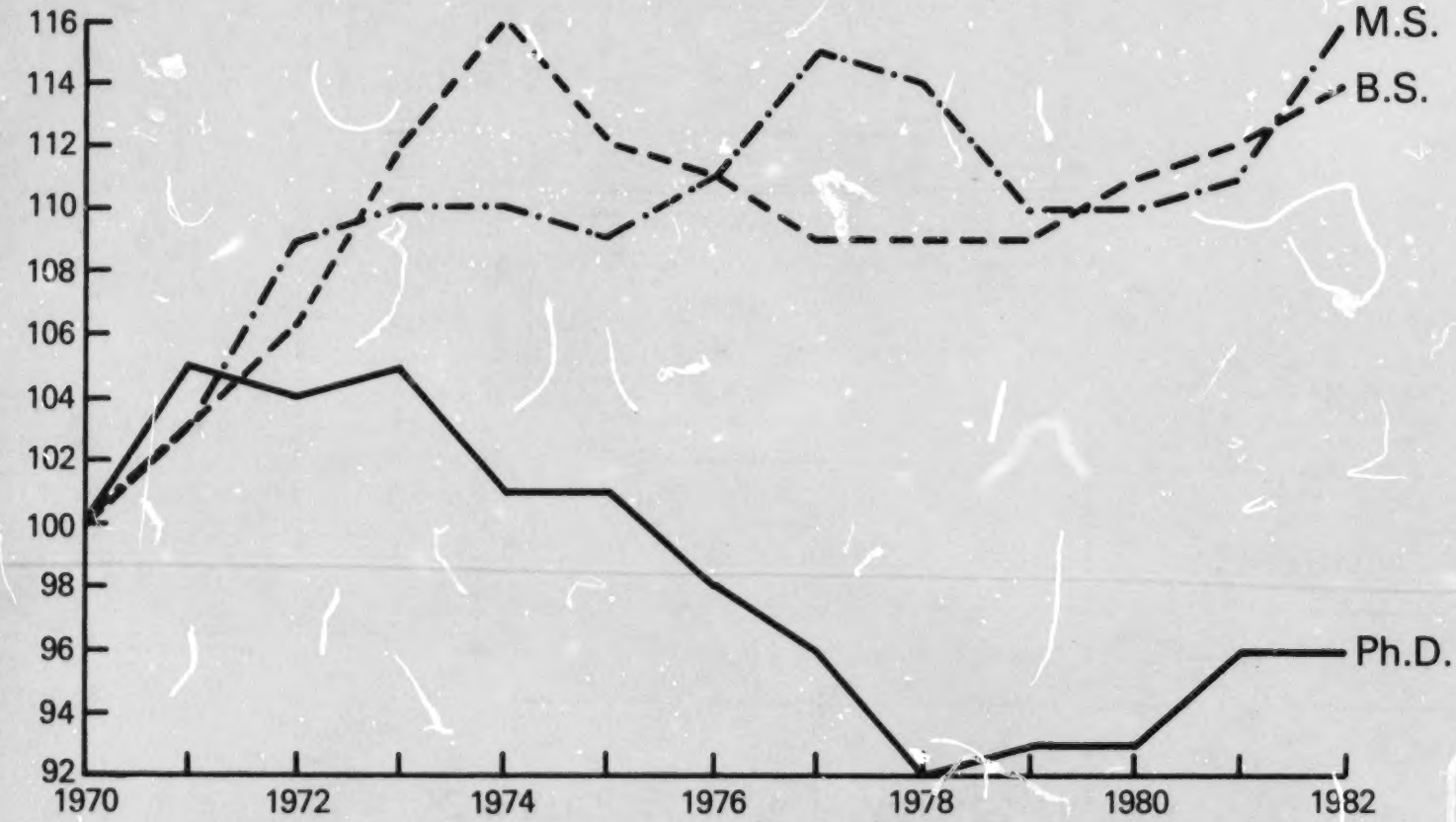
SOURCE: NATIONAL SCIENCE FOUNDATION

SRS 84-315

Chart 1

INDEX OF SCIENCE/ENGINEERING DEGREE PRODUCTION

(1970 = 100)



SOURCES: NATIONAL SCIENCE FOUNDATION AND
NATIONAL CENTER FOR EDUCATION STATISTICS

SRS 81-3390

Chart 2

CHANGES IN ANNUAL SCIENCE/ENGINEERING BACCALAUREATE PRODUCTION

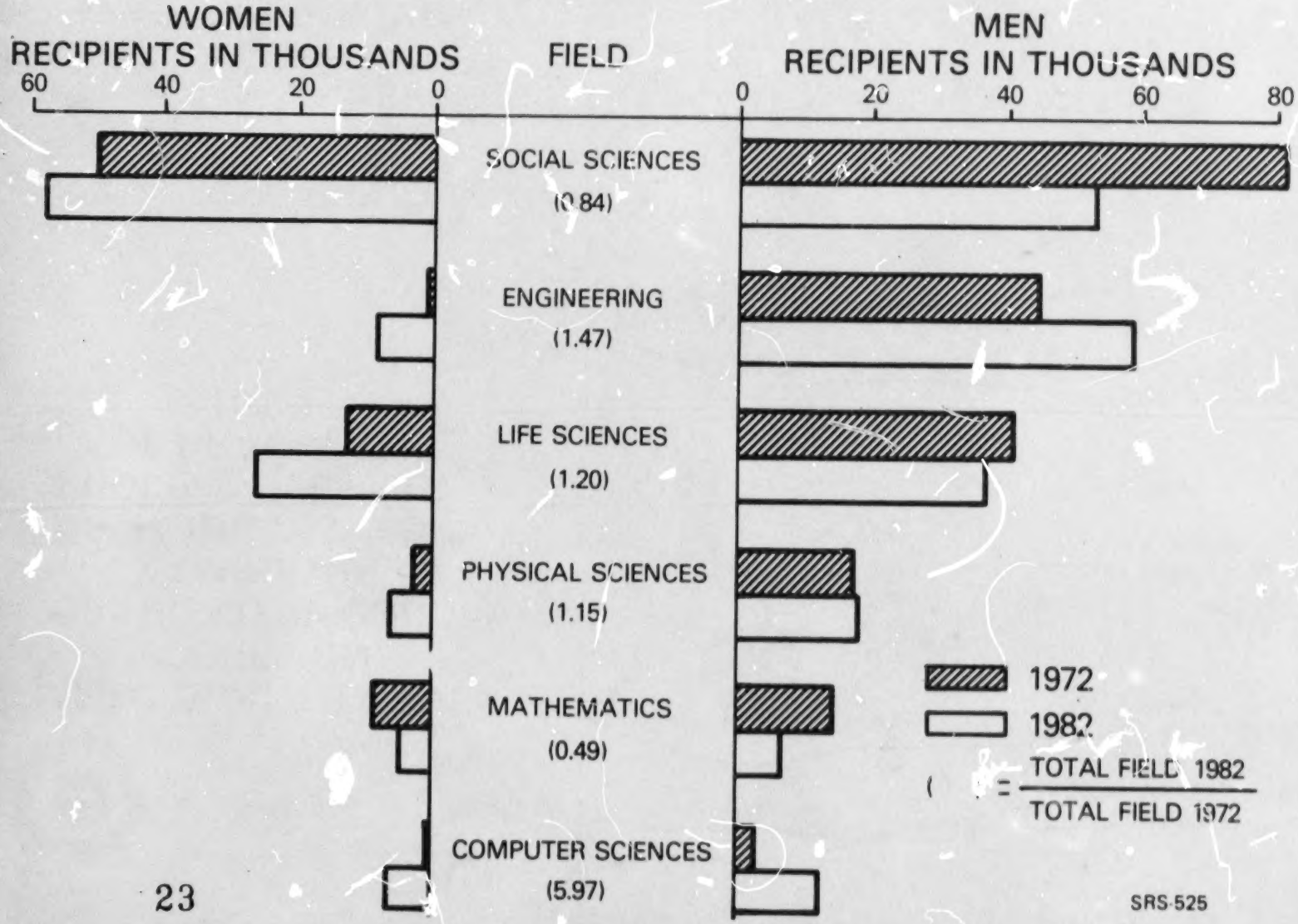


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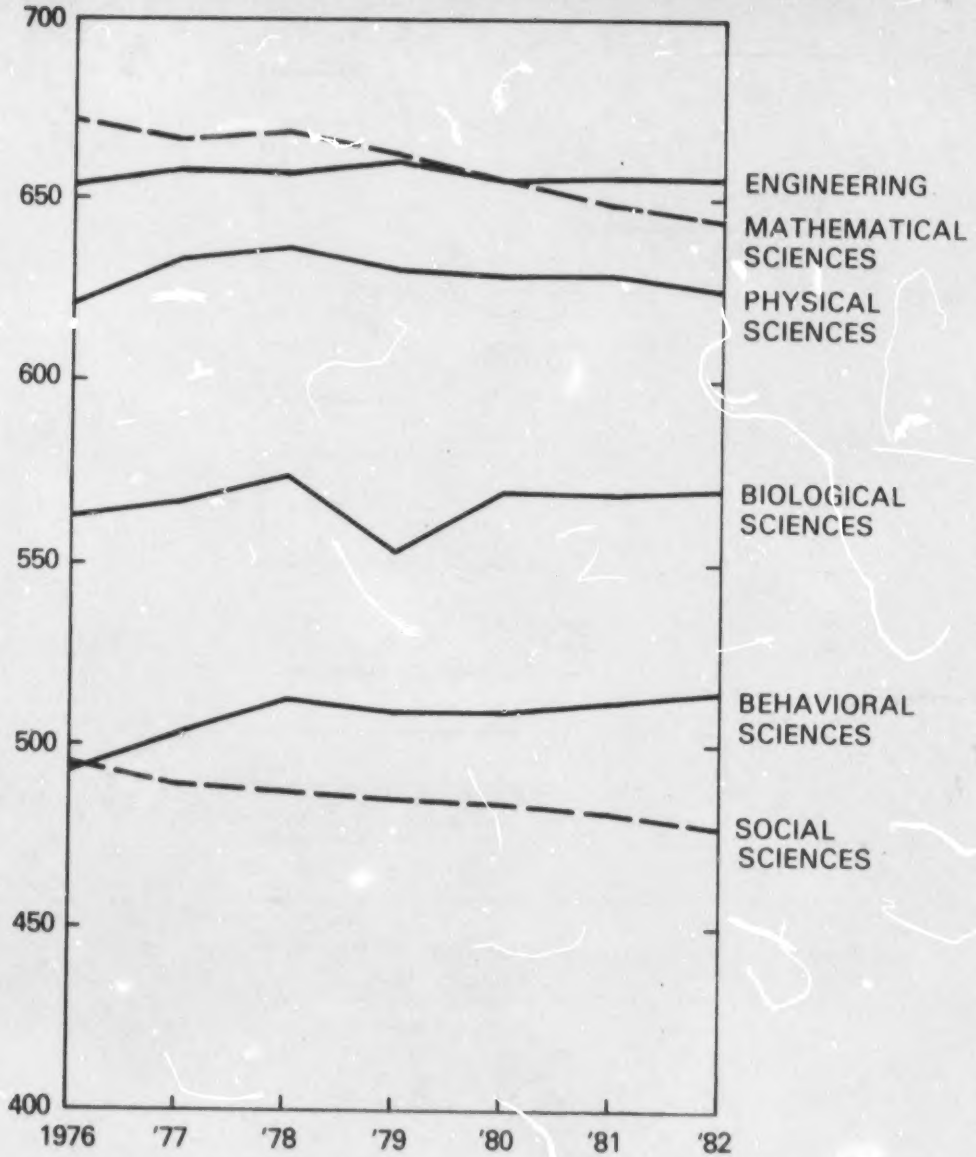
Chart 3

15

MEAN QUANTITATIVE SCORES ON GRADUATE RECORD EXAMINATION APTITUDE TESTS BY PROSPECTIVE FIELD OF GRADUATE STUDY



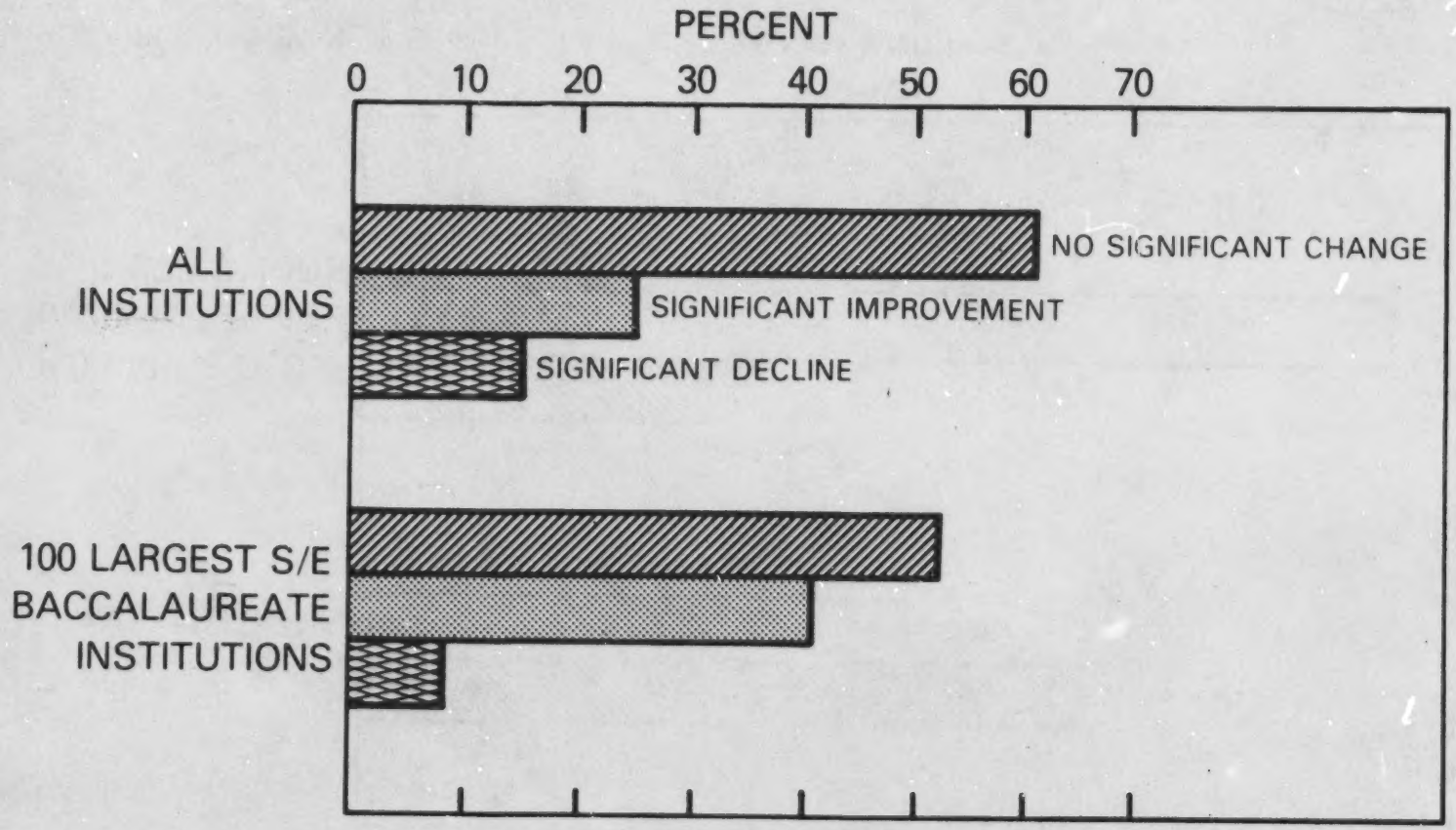
SRS 82 1761

SOURCE: EDUCATIONAL TESTING SERVICE

Chart 4

16

PERCEPTIONS OF CHANGE IN QUALITY OF S/E UNDERGRADUATES: 1977-82



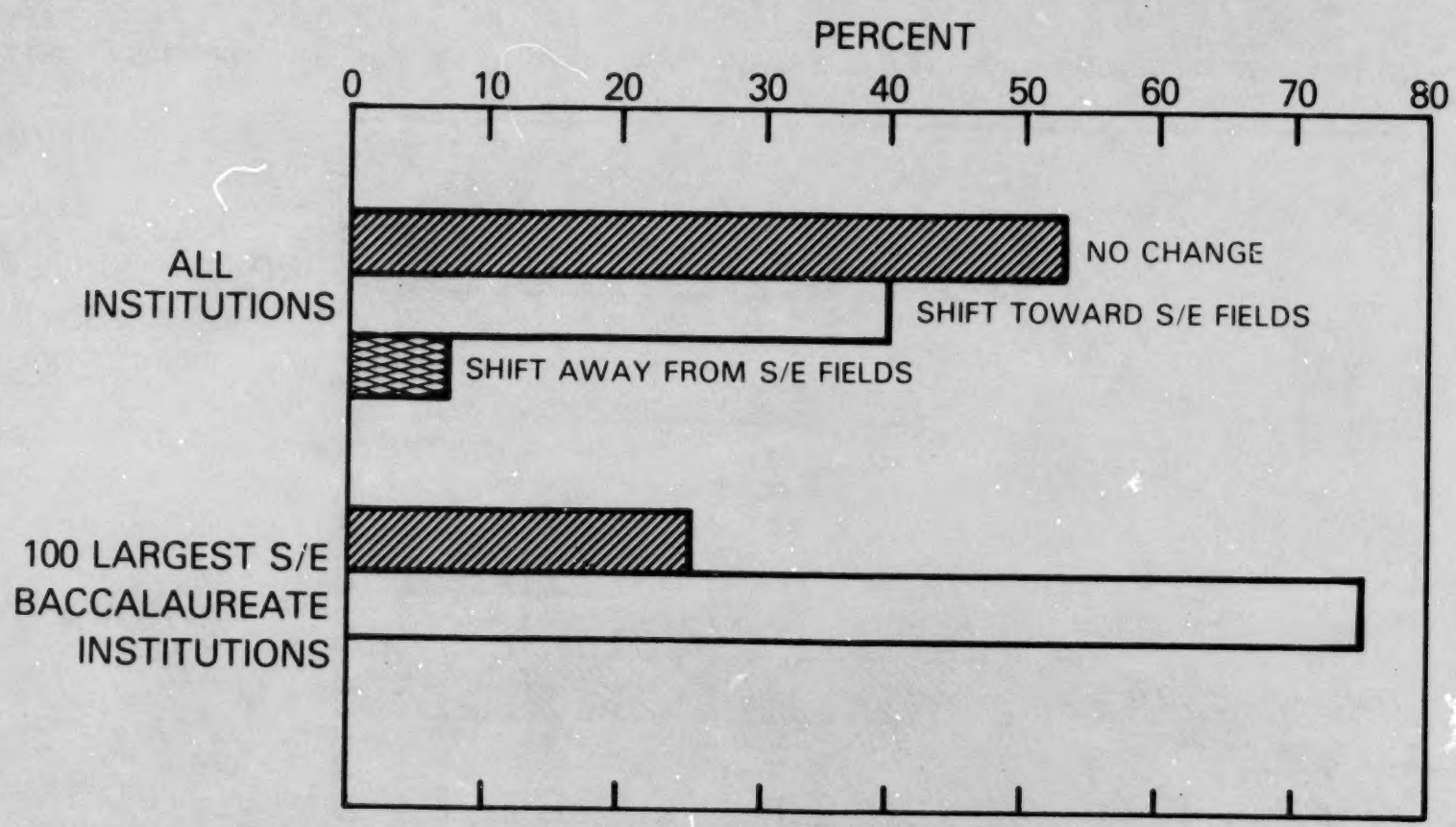
SOURCES: DIVISION OF SCIENCE RESOURCES STUDIES/STIA, AMERICAN COUNCIL ON EDUCATION

SRS 84-323

Chart 5

17

OPINIONS ON SHIFT IN DISTRIBUTION OF MOST ABLE UNDERGRADUATES: 1977-82

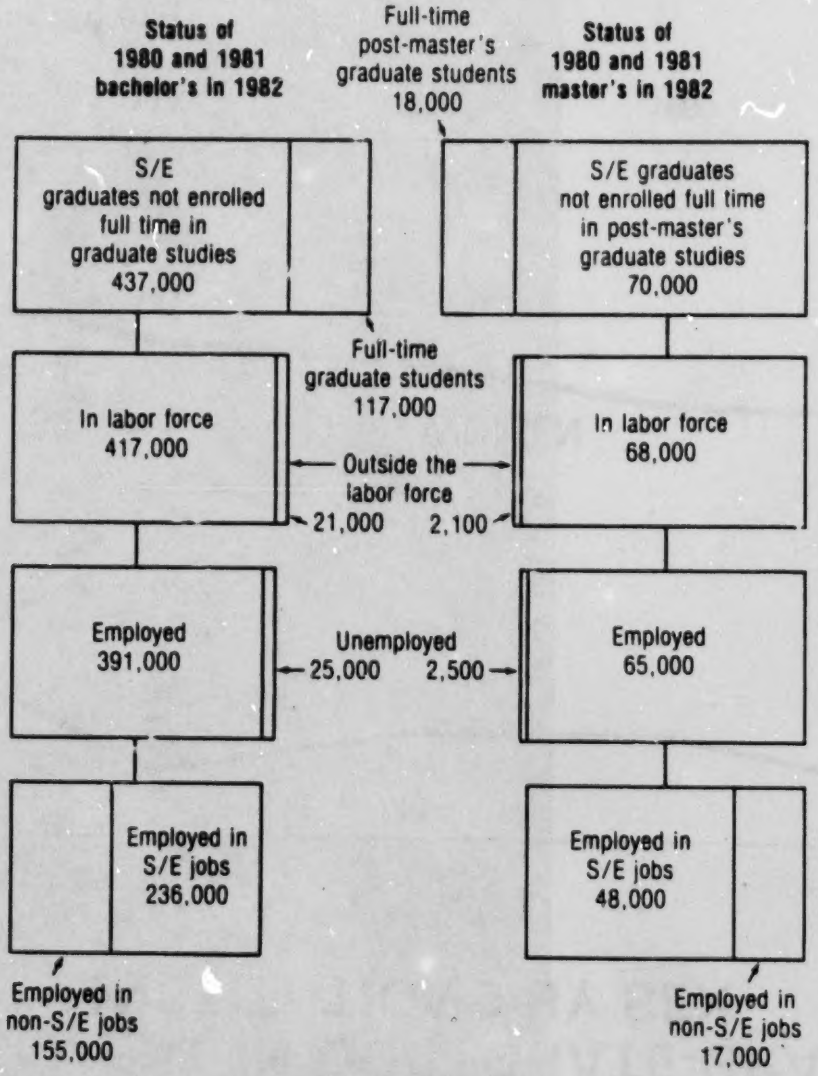


SOURCE: DIVISION OF SCIENCE RESOURCES STUDIES AND AMERICAN COUNCIL ON EDUCATION

SRS 84-324

Chart 6

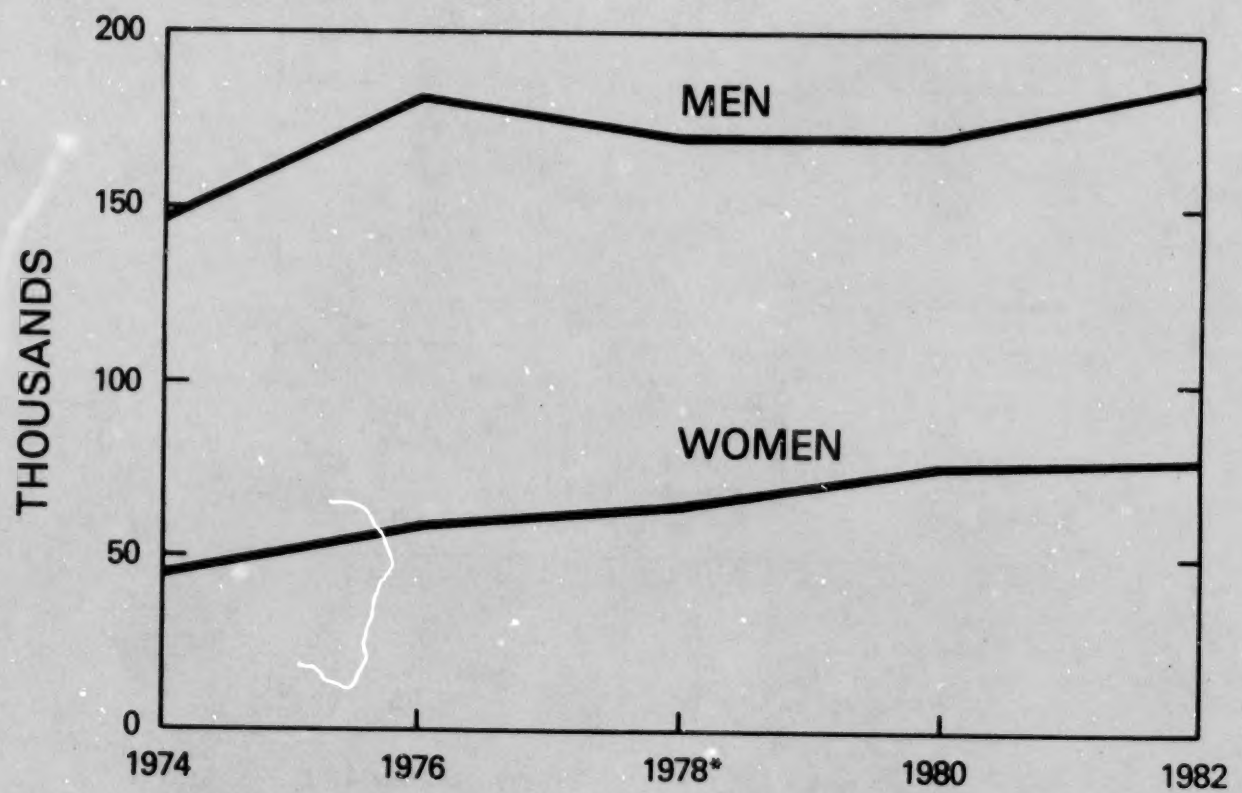
School-to-work transition of science/engineering (S/E) bachelor's- and master's-degree recipients


Status of 1980 and 1981 bachelor's in 1982
Full-time post-master's graduate students 18,000
Status of 1980 and 1981 master's in 1982
S/E graduates not enrolled full time in graduate studies 437,000
S/E graduates not enrolled full time in post-master's graduate studies 70,000
Full-time graduate students 117,000
In labor force 417,000
Outside the labor force
21,000
2,100
In labor force 68,000
Employed 391,000
Unemployed
25,000
2,500
Employed 65,000
Employed in S/E jobs 236,000
Employed in S/E jobs 48,000
Employed in non-S/E jobs 155,000
Employed in non-S/E jobs 17,000

SOURCE: National Science Foundation

SRS-529

FULL-TIME SCIENCE AND ENGINEERING ENROLLMENT IN DOCTORATE-GRANTING INSTITUTIONS BY SEX



*DATA FOR 1978 ARE ESTIMATED

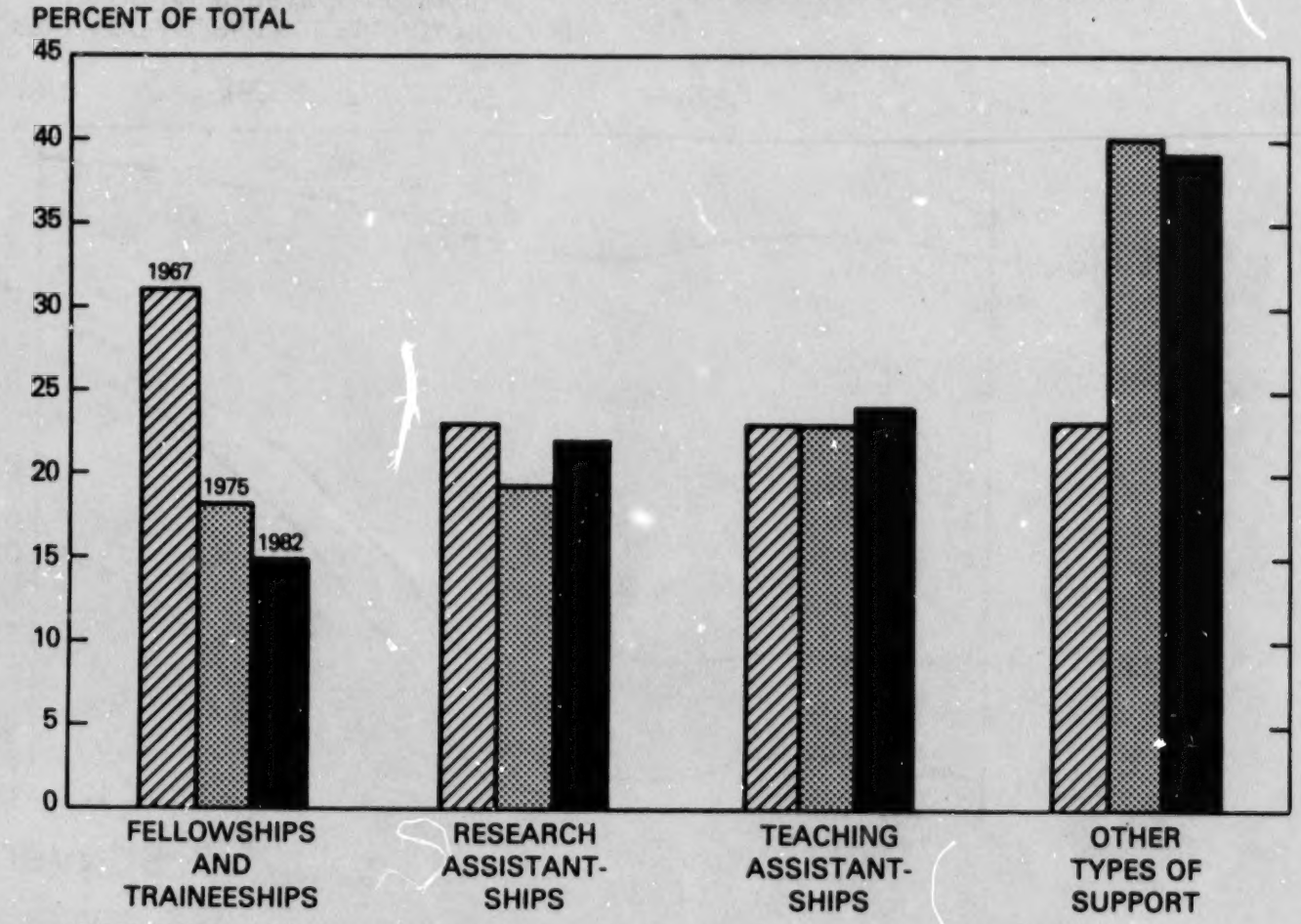
SOURCE: NATIONAL SCIENCE FOUNDATION

SRS 82-1759

Chart 8

20

FULL-TIME GRADUATE SCIENCE/ENGINEERING ENROLLMENT IN DOCTORATE-GRANTING INSTITUTIONS BY TYPE OF MAJOR SUPPORT



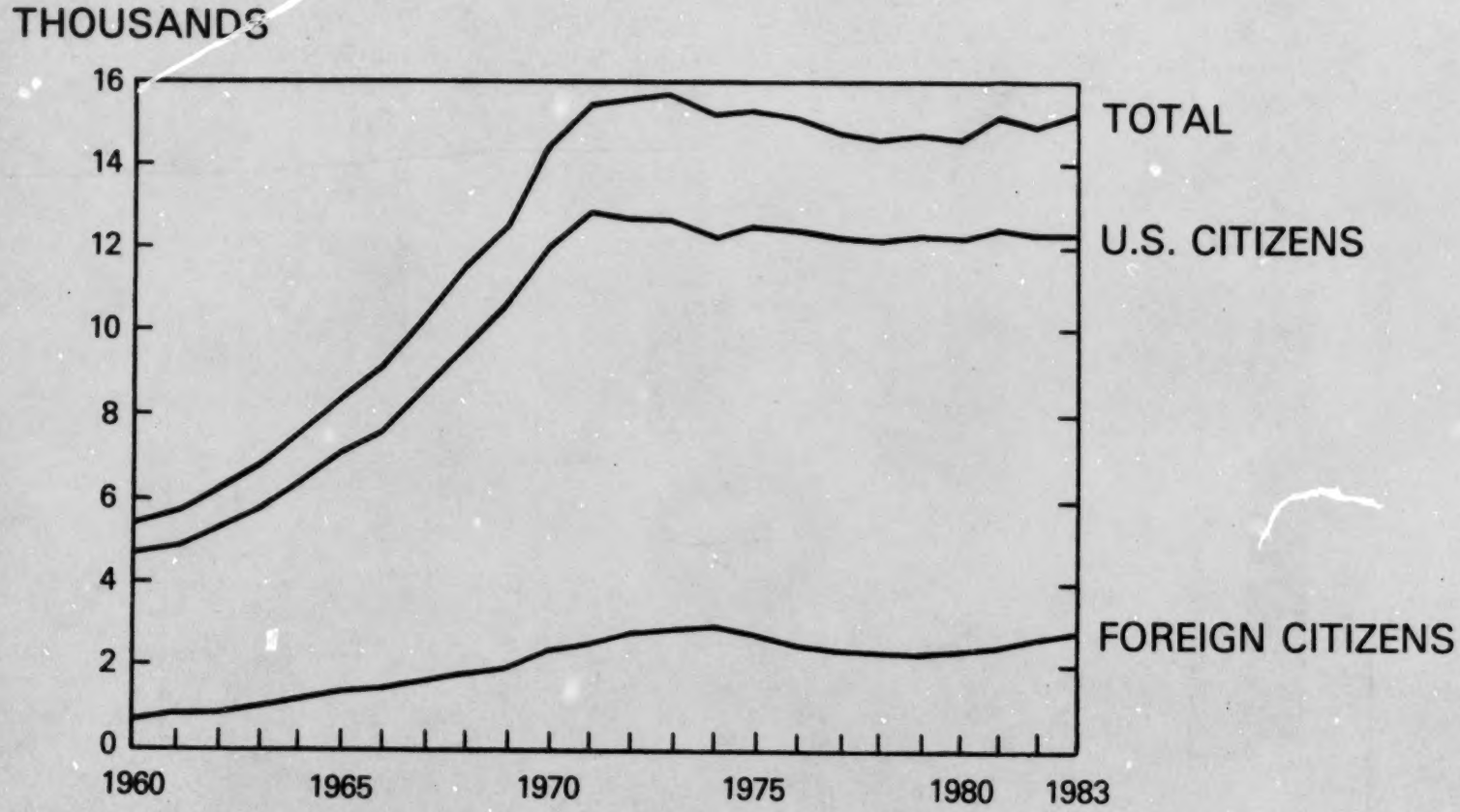
SOURCE: NATIONAL SCIENCE FOUNDATION

SRS 84-251
1-84

Chart 9

21

U.S. SCIENCE DOCTORATE RECIPIENTS BY CITIZENSHIP



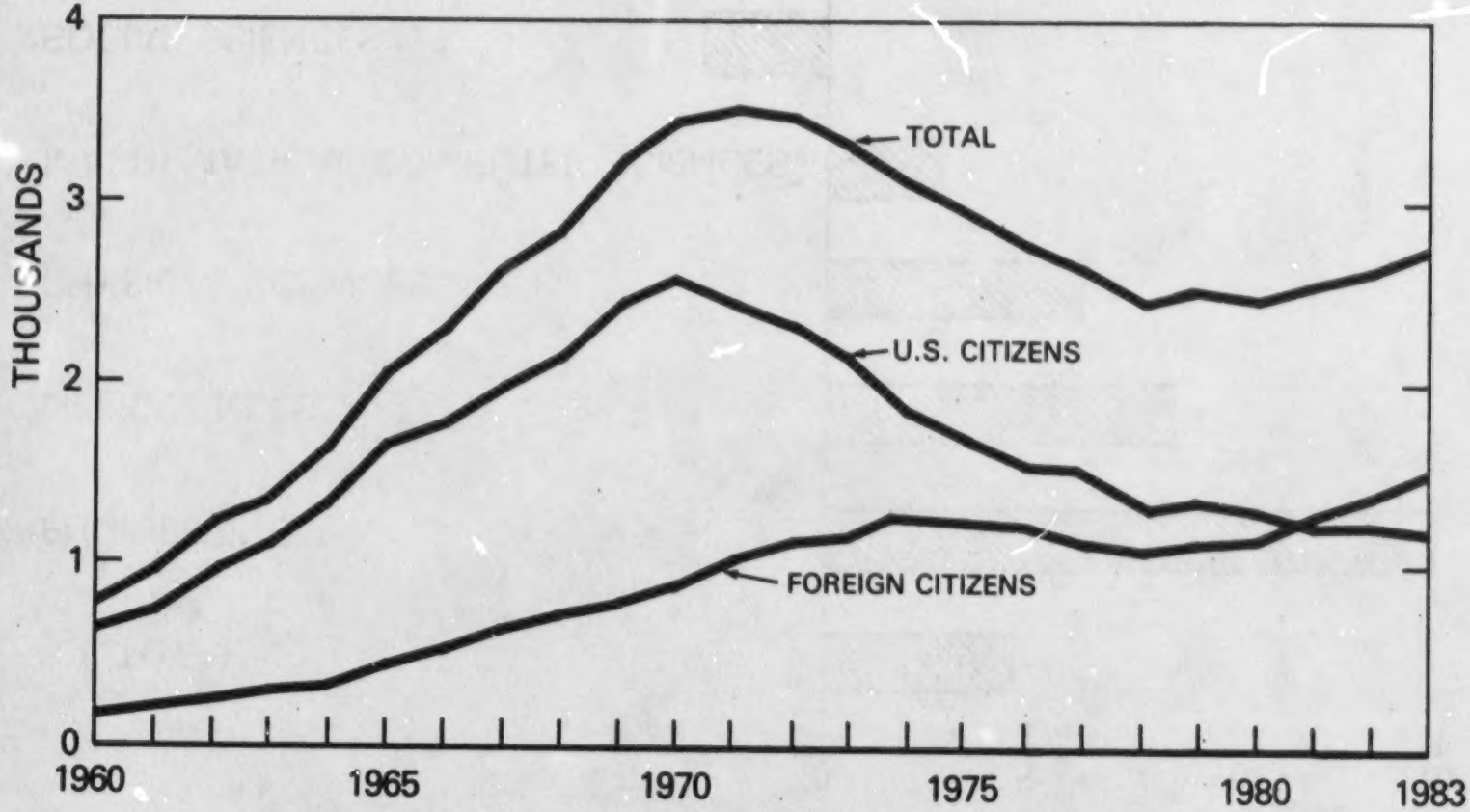
SOURCES: NATIONAL SCIENCE FOUNDATION AND NATIONAL RESEARCH COUNCIL

Chart 10

22

SRS 82-1766

U.S. ENGINEERING DOCTORATE RECIPIENTS BY CITIZENSHIP



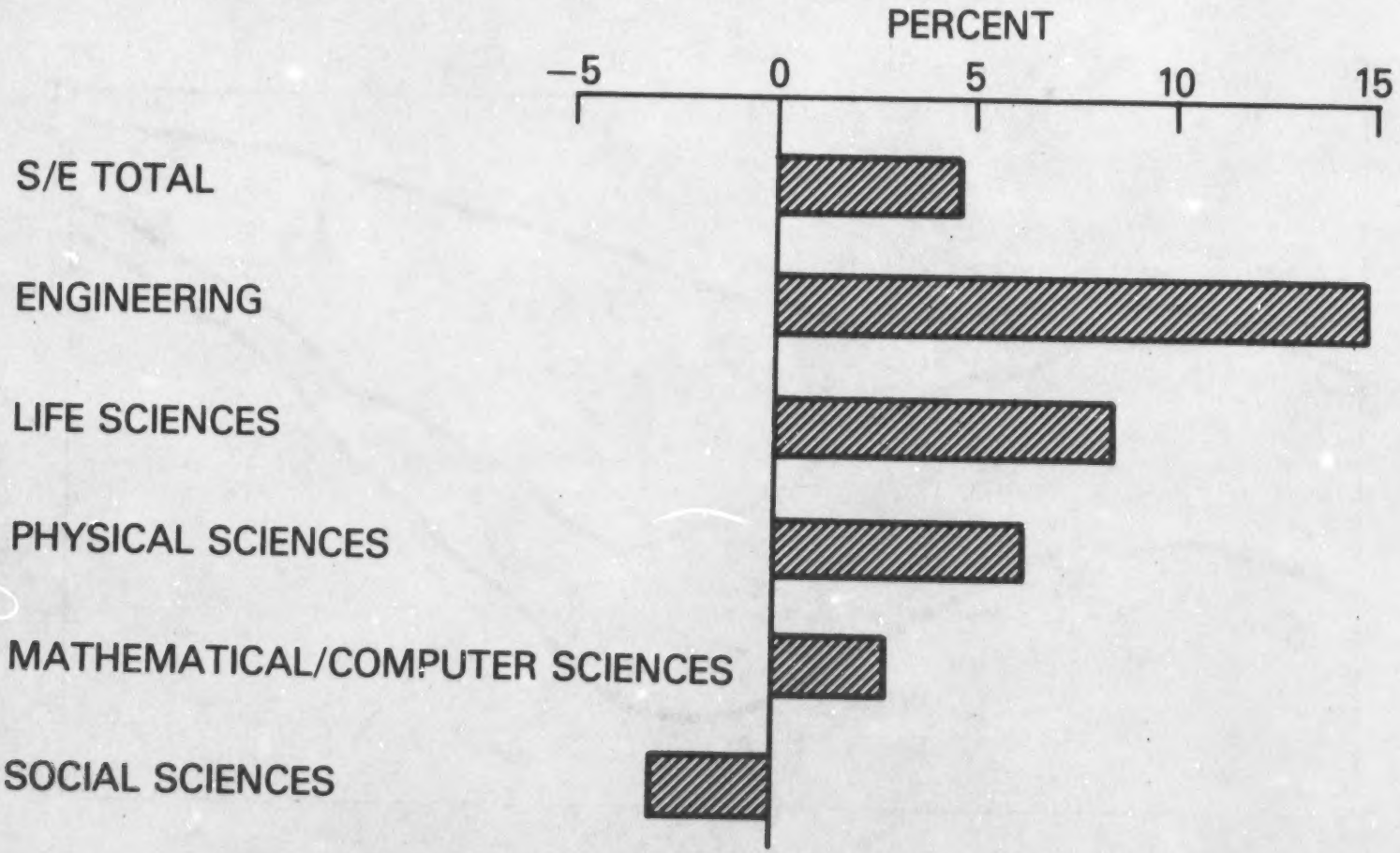
SOURCES: NATIONAL SCIENCE FOUNDATION AND NATIONAL RESEARCH COUNCIL

SRS 80-1816

Chart 11

23

CHANGE IN S/E DOCTORATE PRODUCTION: 1978-83



SOURCE: DIVISION OF SCIENCE RESOURCES STUDIES/STIA

Chart 12

24

SRS 84-321

DISTRIBUTION OF ENGINEERING DOCTORATE RECIPIENTS BY CITIZENSHIP OR RESIDENCY STATUS: 1983

NUMBER OF ENGINEERING DOCTORATES 2,780

PERCENT DISTRIBUTION

U.S. CITIZENS	44
NON-U.S., PERMANENT RESIDENTS	12
NON-U.S., TEMPORARY RESIDENTS	44

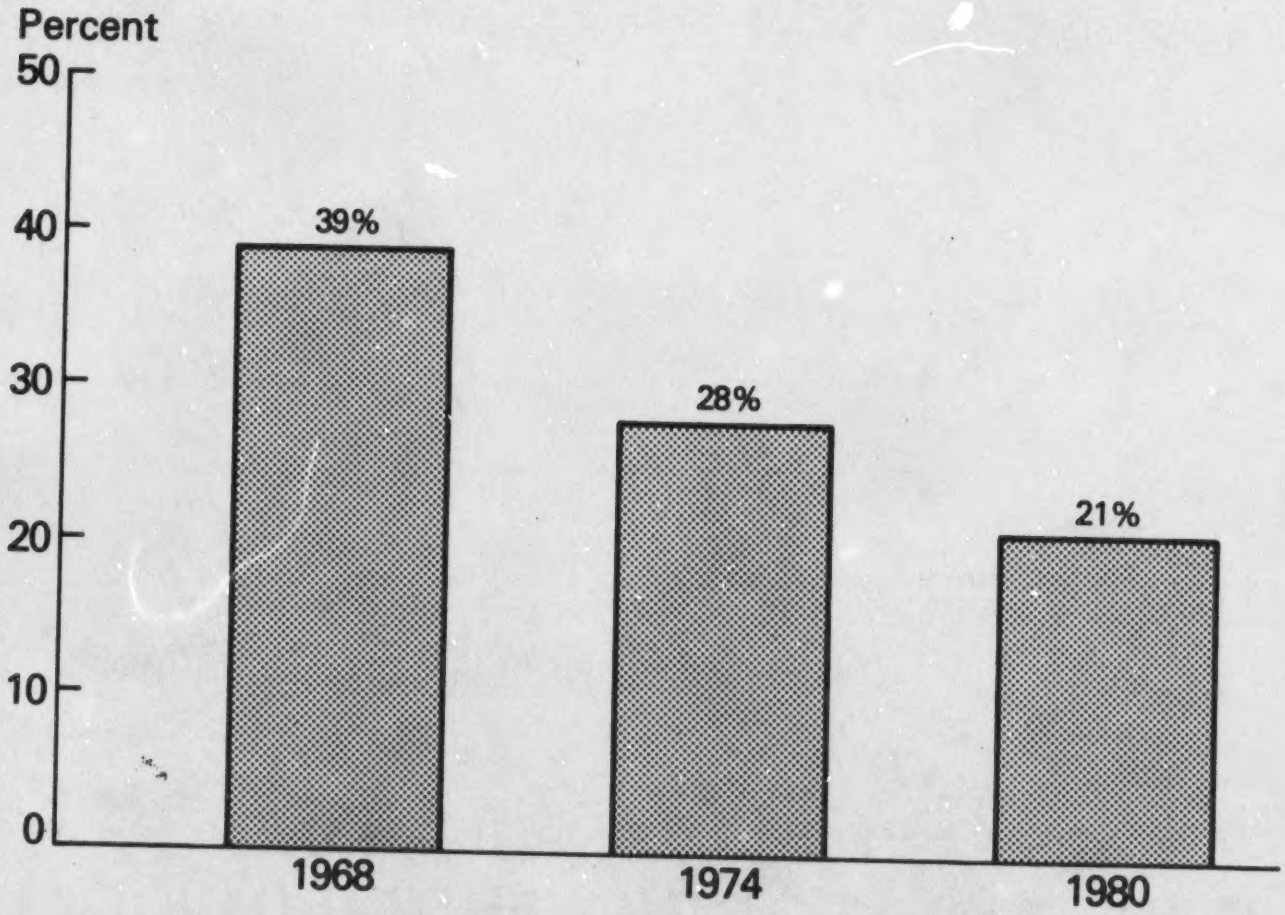
SOURCE: NATIONAL SCIENCE FOUNDATION AND NATIONAL RESEARCH COUNCIL

Chart 13

25

SRS 82-1702

Proportion of Full-Time S/E Faculty Who Are Recent Doctorates



Source: Division of Science Resources Studies/STIA.

SRS 84-333
3-15-84

Chart 14

CHARACTERISTICS OF SCIENCE AND ENGINEERING PERSONNEL SYSTEMS

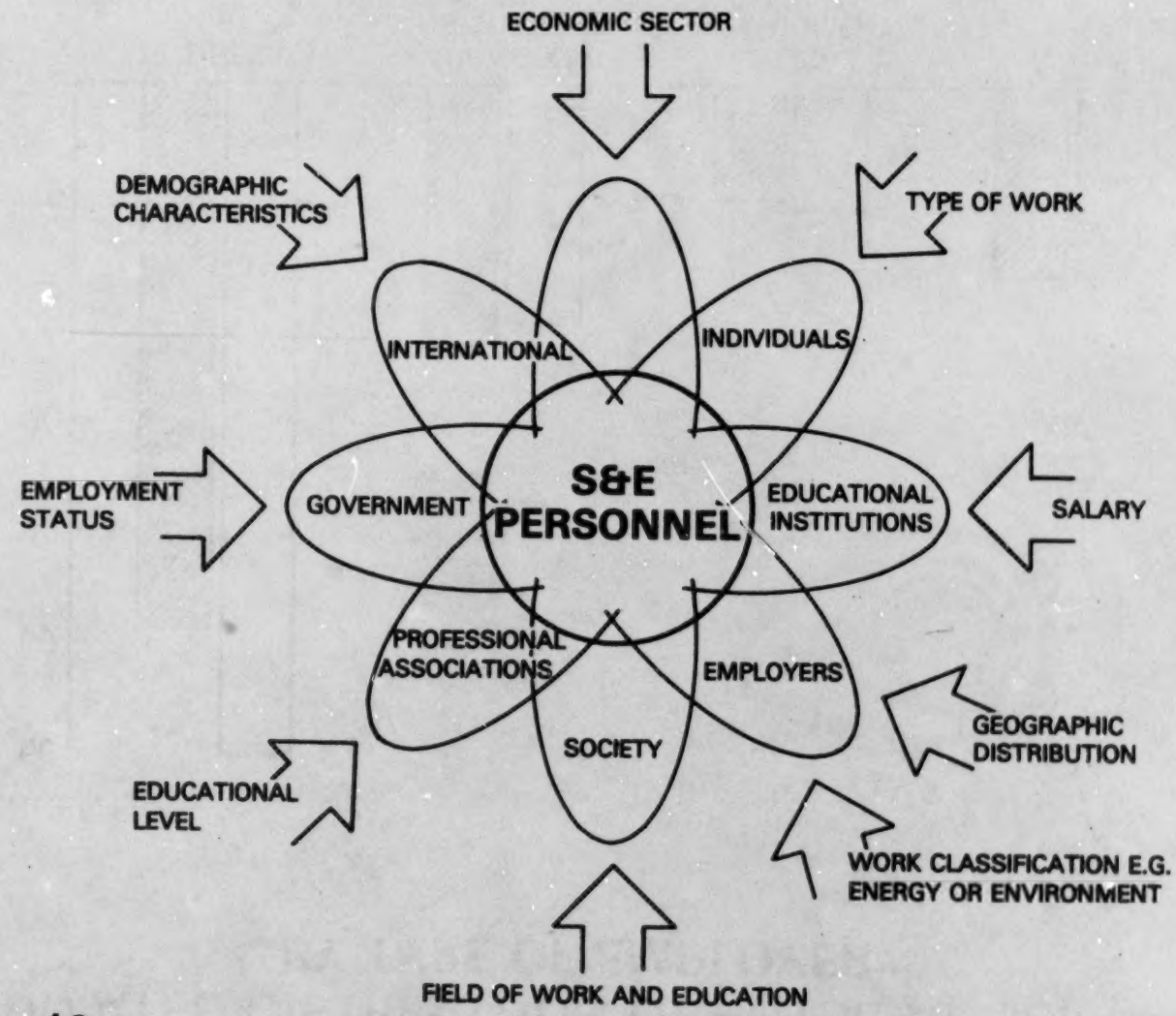
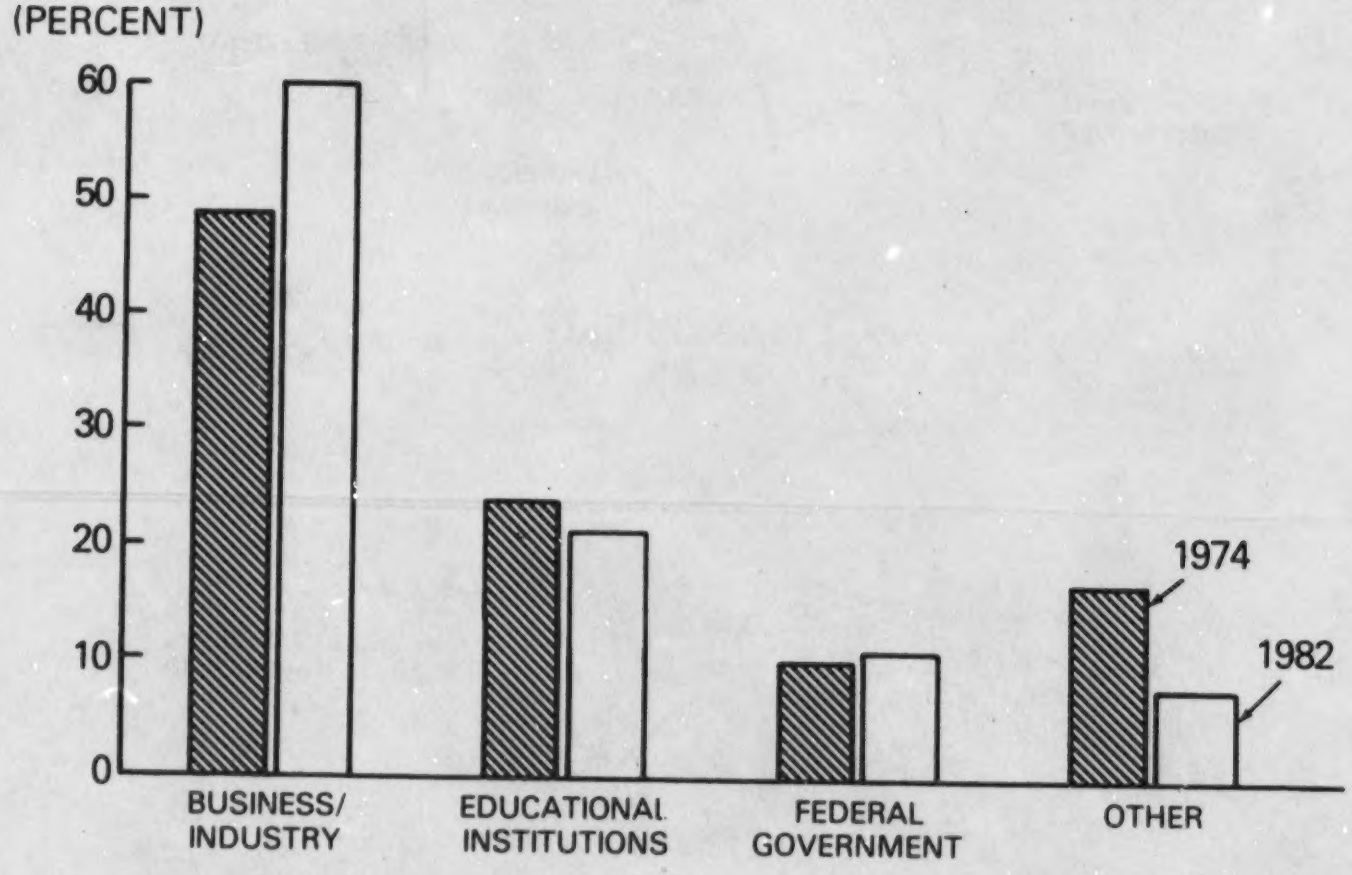


Chart 15

27

ESTIMATED DISTRIBUTION OF PHYSICAL SCIENTISTS BY TYPE OF EMPLOYER

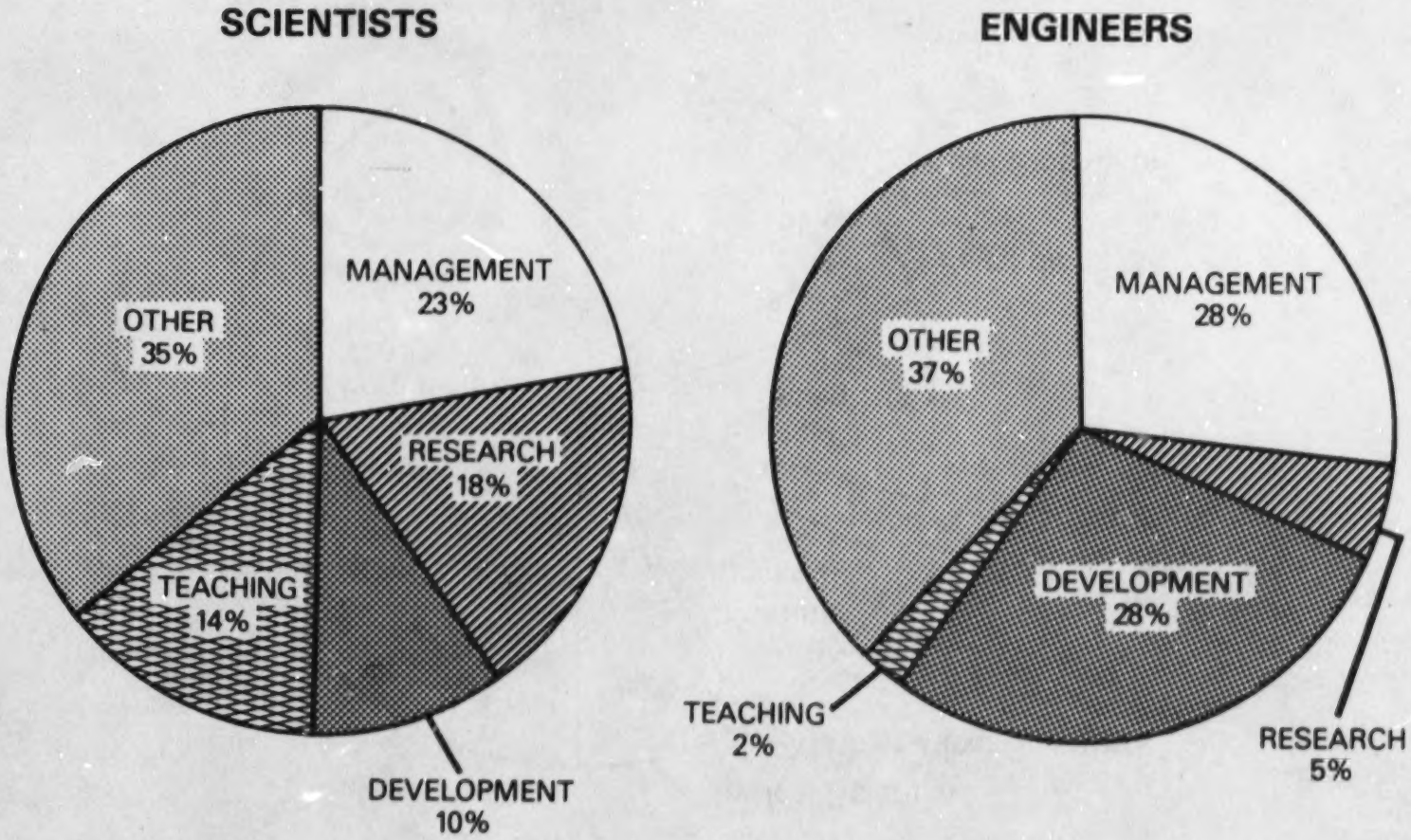


SOURCE: NATIONAL SCIENCE FOUNDATION

4/84
SRS-527

Chart 16

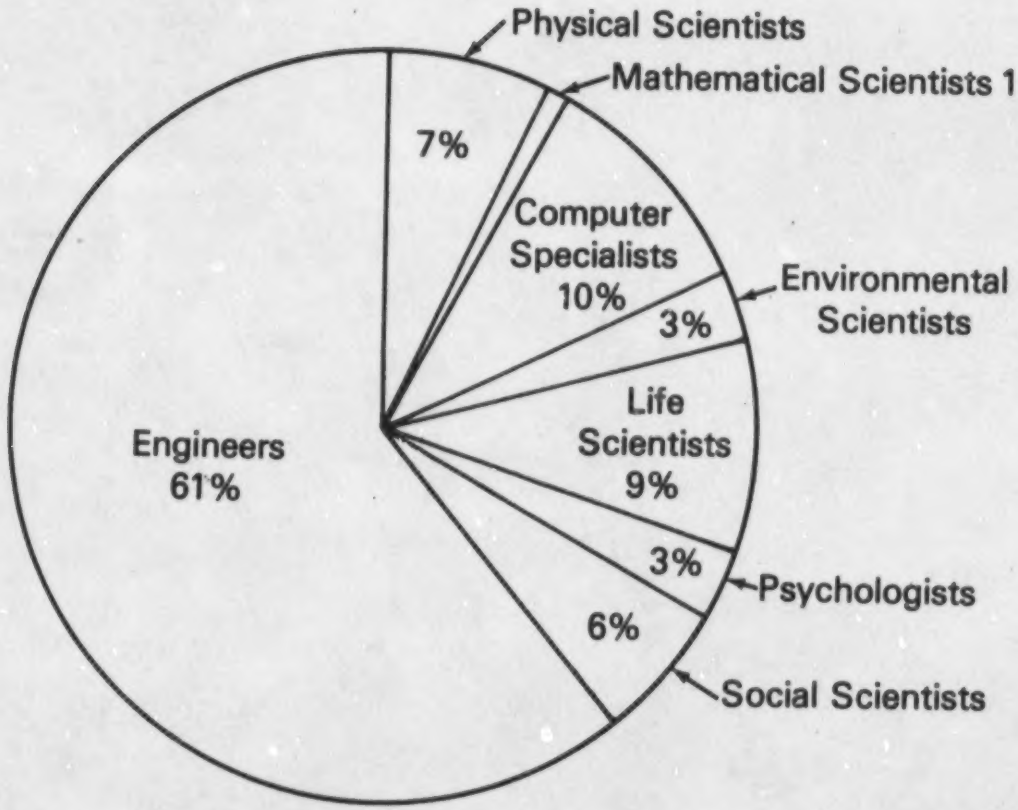
DISTRIBUTION OF SCIENTISTS/AND ENGINEERS BY PRIMARY WORK ACTIVITY: 1982



SOURCE: DIVISION OF SCIENCE RESOURCES STUDIES/STIA

4/84
SRS-526

Employed **Men** Scientists and Engineers: 1982



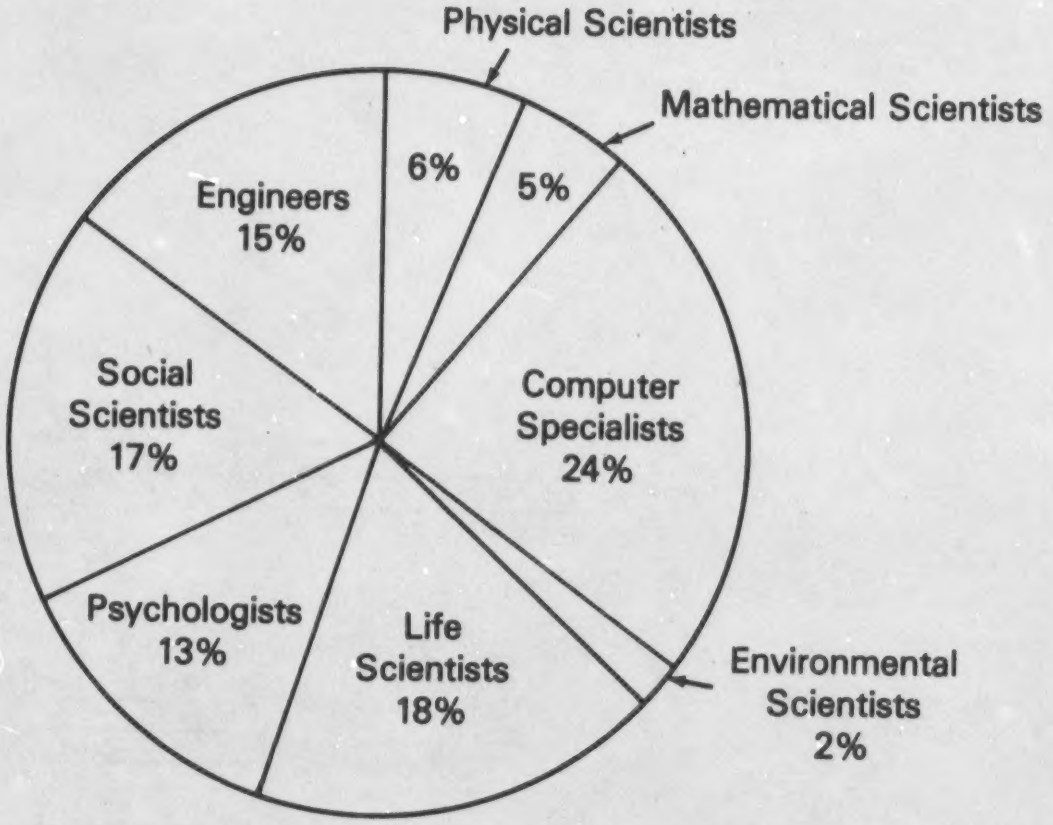
Source: Division of Science Resources Studies/STIA.

SRS 84-294

Chart 18

30

Employed Women Scientists and Engineers: 1982



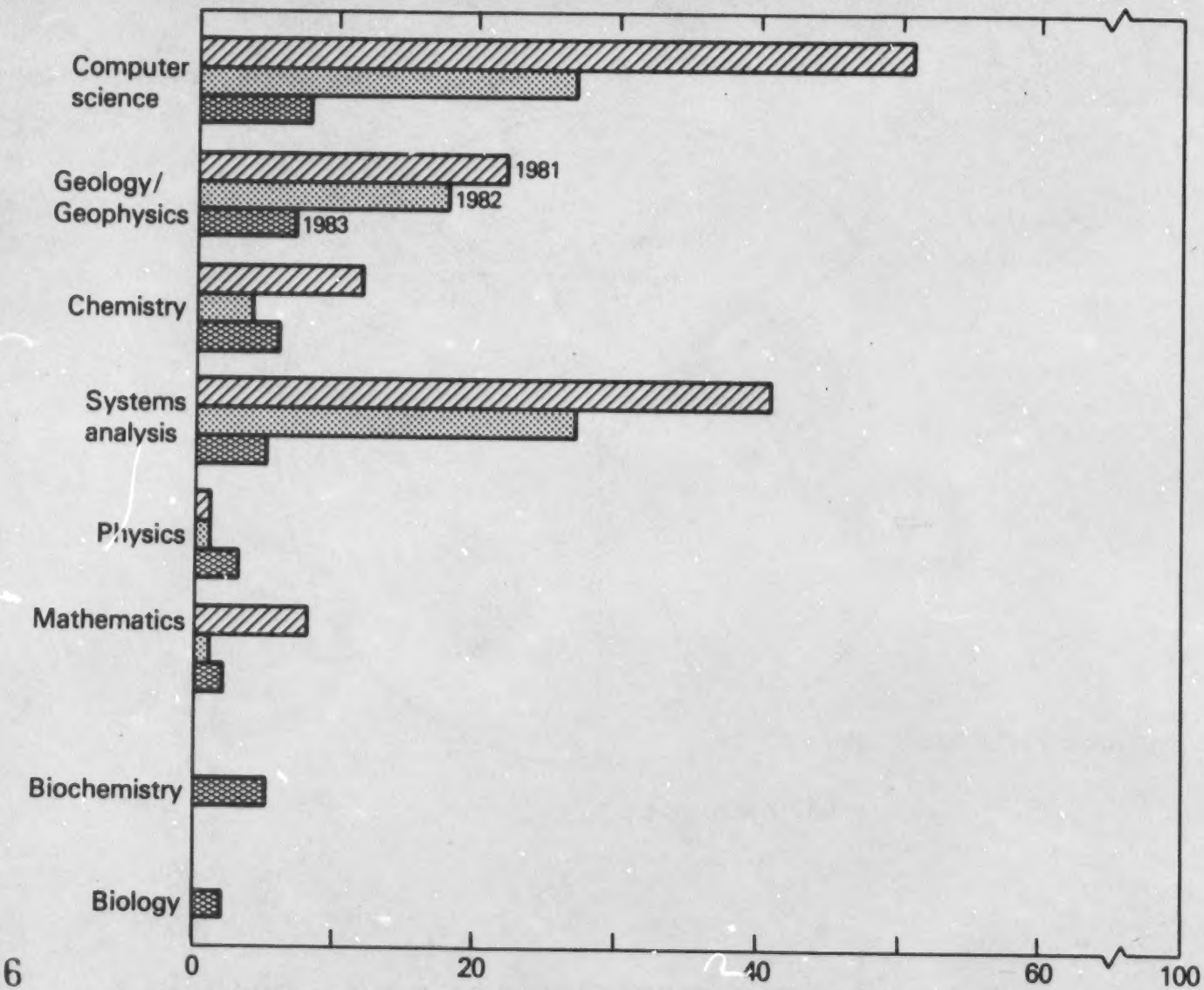
Source: Division of Science Resources Studies/STIA.

SRS 84-295

Chart 19

Chart 20

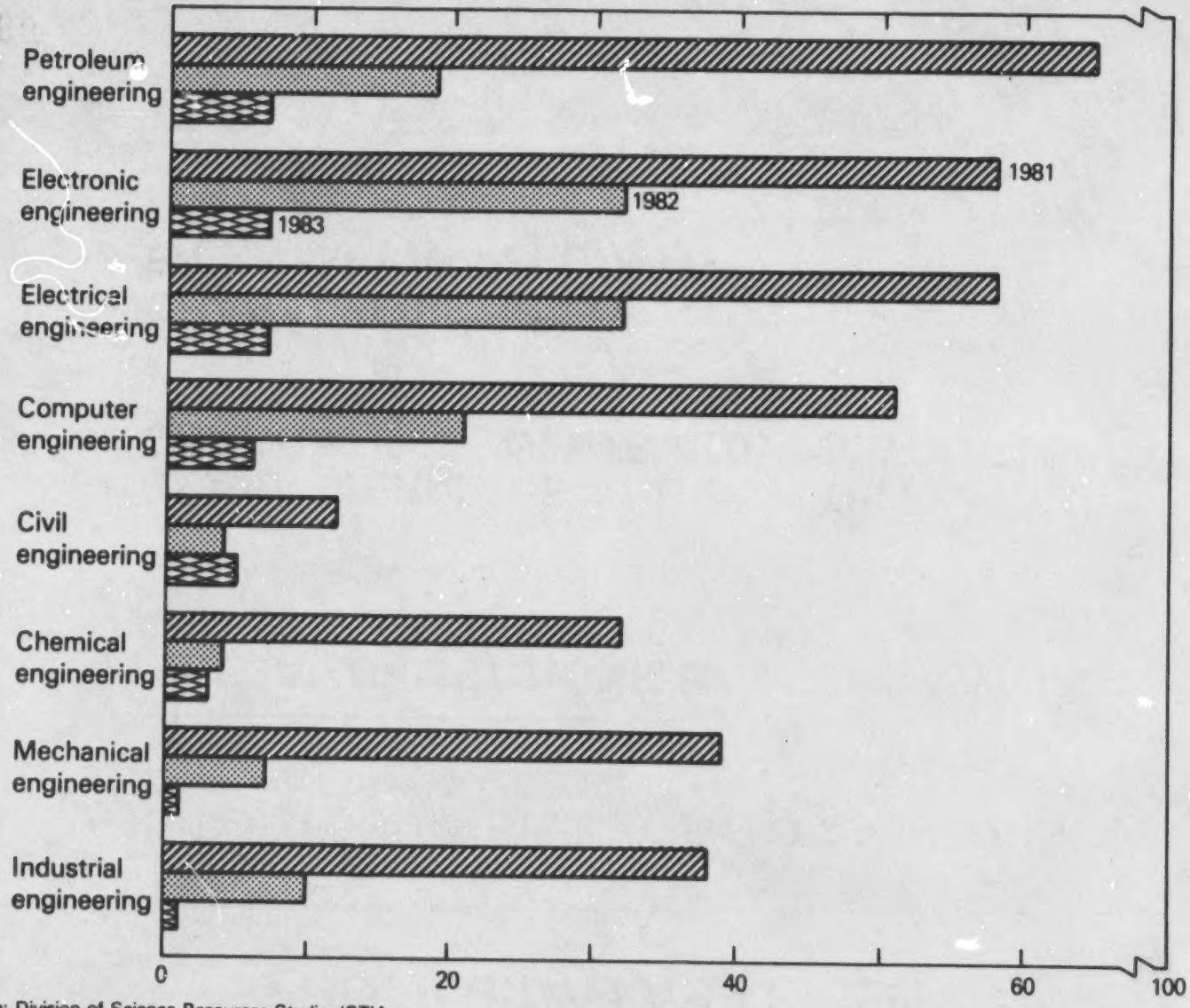
Percent of Firms Reporting Shortage of Scientists



Source: Division of Science Resources Studies/STIA.

SRS 84-298

Percent of Firms Reporting Shortage of Engineers



Source: Division of Science Resources Studies/STIA.

SRS 84-299

Chart 21

33

PROFILE DATA ELEMENTS

- R&D EXPENDITURES BY FIELD AND SOURCE
- FEDERAL OBLIGATIONS BY AGENCY, FIELD, AND TYPE OF SUPPORT
- CHARACTERISTICS AND SUPPORT OF GRADUATE STUDENTS AND POSTDOCTORATES
- CHARACTERISTICS OF SCIENTIFIC AND ENGINEERING PERSONNEL

001775
UNIVERSITY OF ILLINOIS AT URBANA
Public
Doctorate-Granting
NCES INSTITUTIONAL CLASSIFICATION: A02

DATA ELEMENTS ON U.S. UTILIZATION OF SCIENTISTS AND ENGINEERS

DATA ELEMENT	NATIONAL TOTALS		INDUSTRY		UNIVERSITIES & COLLEGES		NONPROFIT INSTITUTIONS		GOVERNMENT			
									FEDERAL		OTHER	
	PH. D.	OTHER	PH. D.	OTHER	PH. D.	OTHER	PH. D.	OTHER	PH. D.	OTHER	PH. D.	OTHER
TOTAL	●	●	●	●	●	●	◒	●	●	●	◒	◒
SEX	●	●	●	●	●	●	◒	◒	●	●	●	◒
AGE	●	●	●	●	●	●	◒	◒	●	●	●	◒
RACE/ETHNIC ORIGIN	●	◒	●	◒	●	◒	◒	◒	●	◒	●	◒
EDUCATION -												
• HIGHEST DEGREE	●	●	●	●	●	●	◒	●	●	●	●	◒
• FIELD OF STUDY	●	●	●	●	●	●	◒	◒	●	●	●	◒
OCCUPATION	●	●	●	●	●	●	◒	●	●	●	●	◒
TYPE OF EMPLOYER	●	●	●	●	●	●	◒	●	●	●	●	◒
WORK ACTIVITY	●	●	●	●	●	●	◒	●	●	●	●	◒
REASON FOR NON-S&E EMPLOYMENT	●	◒	●	◒	●	◒	◒	◒	●	◒	●	◒
UNEMPLOYMENT	●	◒	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SALARY	●	◒	●	◒	●	◒	◒	◒	●	●	●	◒
SOURCE OF SUPPORT	●	●	●	●	●	●	●	●	●	●	●	◒

● - AVAILABLE

◒ - AVAILABLE, BUT WITH LARGE SAMPLING ERRORS (>10%) OR PARTIALLY AVAILABLE

○ NOT AVAILABLE

NA - NOT APPLICABLE

SOURCE: NATIONAL SCIENCE FOUNDATION – SRS

3/82

Beverly Porter, director of manpower studies at the American Institute of Physics, discussed prospects for the future talent pool of physicists.

Physics is a relatively small field with a rather tumultuous past and a potentially exciting future. Production currently involves about 4,500 bachelors, 1,500 masters and slightly over 900 Ph.D.'s a year. All do not go on to become physicists, not even among the Ph.D.'s, but frequently provide manpower resources to neighboring areas of science, engineering and the professions. They are found working across the employment spectrum from academe to industry. In addition to their ease of mobility into various areas, they have traditionally exhibited other characteristics. At all degree levels, few are women and even fewer are indigenous U.S. minorities. As we'll note shortly, some changes have occurred in these areas, but they have been slight. The major change, at the graduate level, has been the recent large increase in the foreign student component.

Let me, then, briefly review some of the trends of the past decades and then talk about the future - both prospects and questions for consideration.

Enrollments and degrees in physics rose steadily through the sixties, dropped through the seventies, and in the eighties, as employment opportunities are increasing, remain stable. There is a growing shortage of high school physics teachers, although fewer students take physics at that level than in earlier years.

At the graduate level, first year enrollments dropped throughout the seventies, and the increase in the eighties is made up wholly of foreign students (chart 1). Post graduation plans of physics bachelor's graduates show decreasing numbers entering graduate study, but increasing numbers entering employment beginning in the late seventies (chart 2).

Physics doctoral graduates are less likely to have stayed in physics, than graduates in other fields (chart 3) with only 61% working in their field in 1981, compared with 82% in engineering, 84% in computer science and 85% in earth and environmental sciences.

The proportion of women in physics shows almost no growth since 1973, compared to substantial growth in other science fields (chart 4). Further, the proportion of women in physics is the smallest of any of the science fields. Doctoral awards to women (chart 5) show similar patterns.

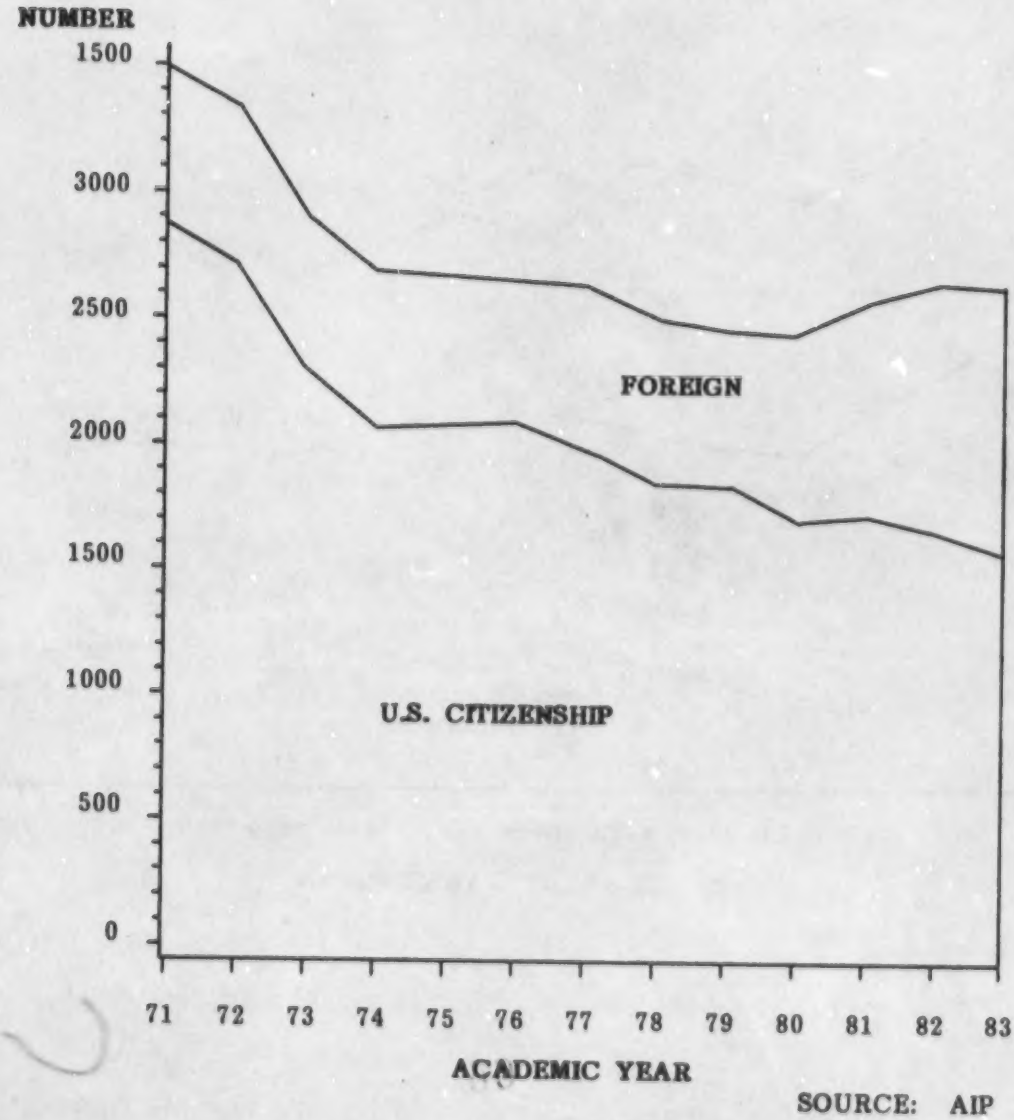
Physics doctoral production over time shows that it is staying fairly level, but with some increase projected through this decade, made up entirely of non-U.S. citizens (chart 6). Projections through this century indicate a probable decline in physics Ph.D. production after 1990 (chart 7) together with a further increase of foreign recipients and a decrease among U.S. citizens (chart 8).

In this brief presentation, I've left out many dimensions which may affect the potential pool of physicists in the future, both economic and intellectual. There is likely to be keen competition among the sciences for the bright minds of tomorrow. Physics will continue, I believe, to be an exciting mode of

inquiry. However, if it is to attract both tomorrow's traditional male students and the women, minorities and other non-traditional groups neglected in the past, it will need to communicate that excitement to all students in a fuller manner than it has recently - from high school through college to graduate school.

CHART 1

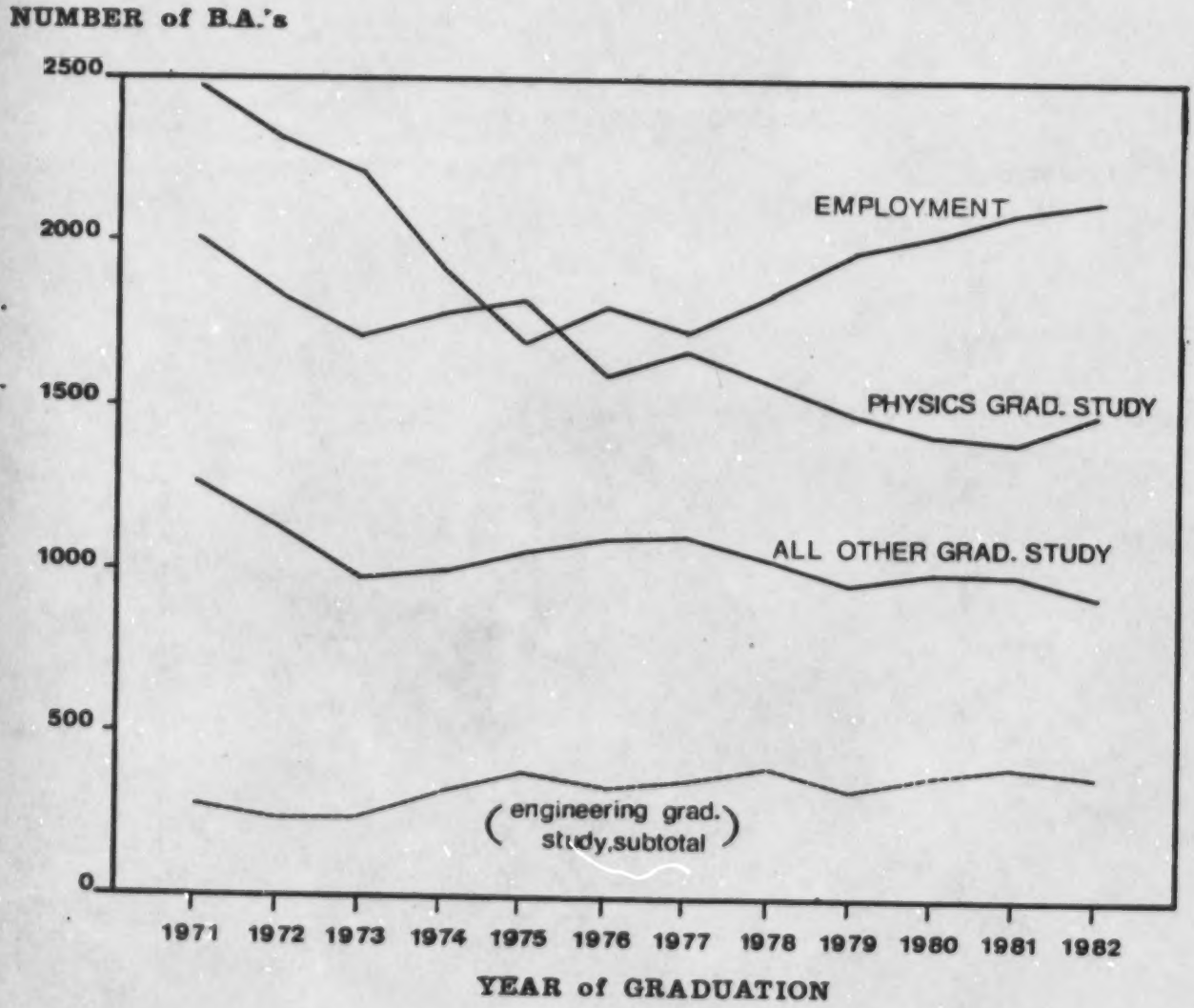
FIRST YEAR GRADUATE PHYSICS STUDENTS BY CITIZENSHIP, 1970-1983



SOURCE: AIP

Chart 2

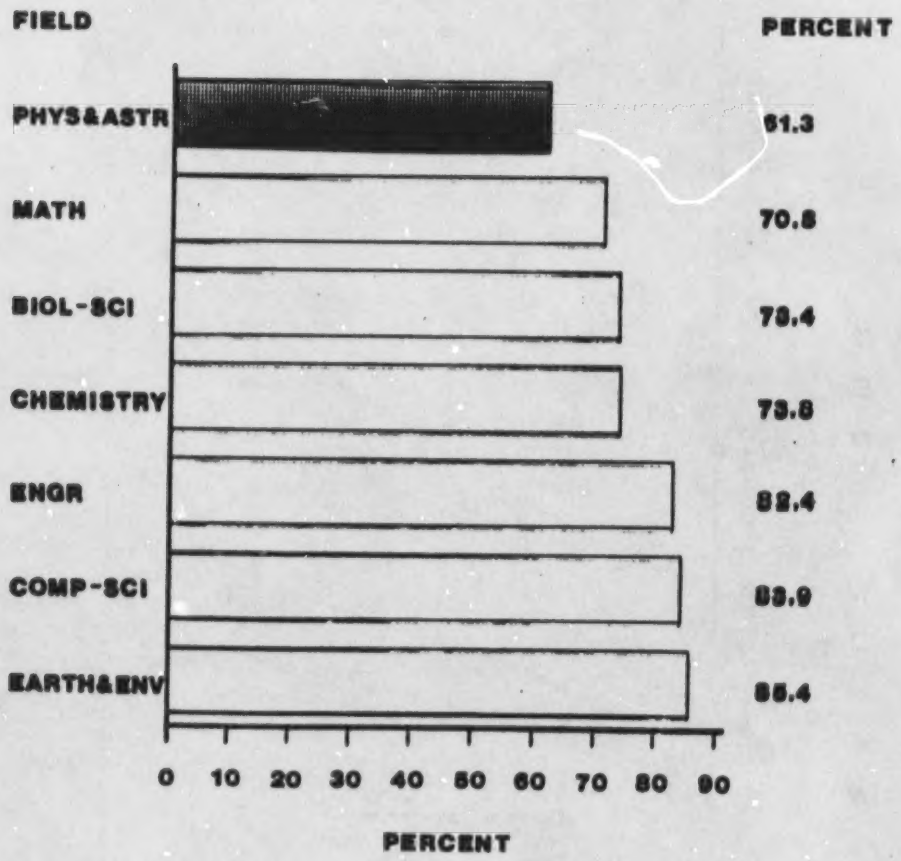
POSTBACCALAUREATE PLANS OF PHYSICS B.A.'s BY YEAR OF DEGREE, 1971-1982.



SOURCE: AIP

Chart 3

RETENTION OF DOCTORAL SCIENTISTS & ENGINEERS BY FIELD, 1981.



SOURCE: NATIONAL ACADEMY OF SCIENCE.

Chart 4

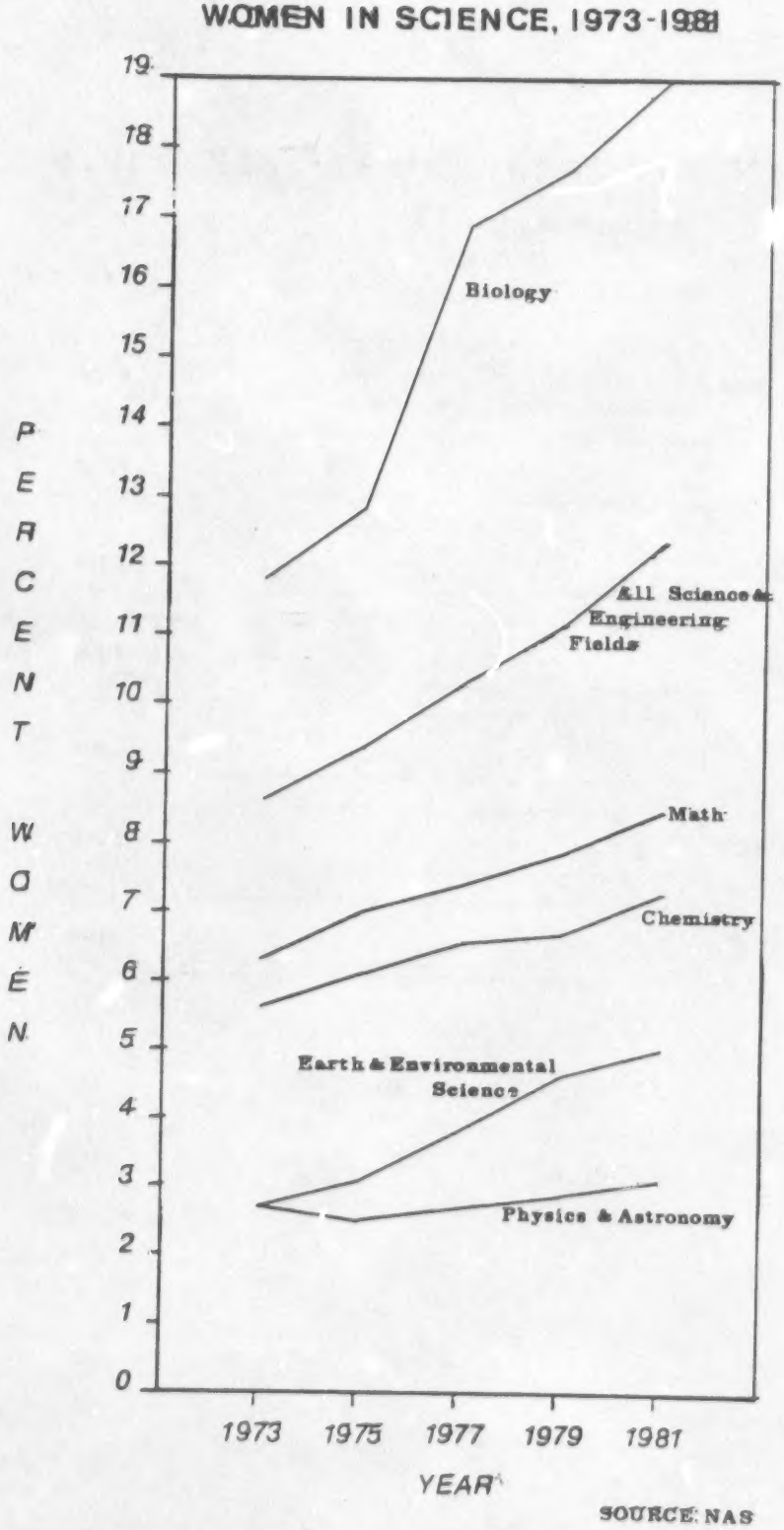
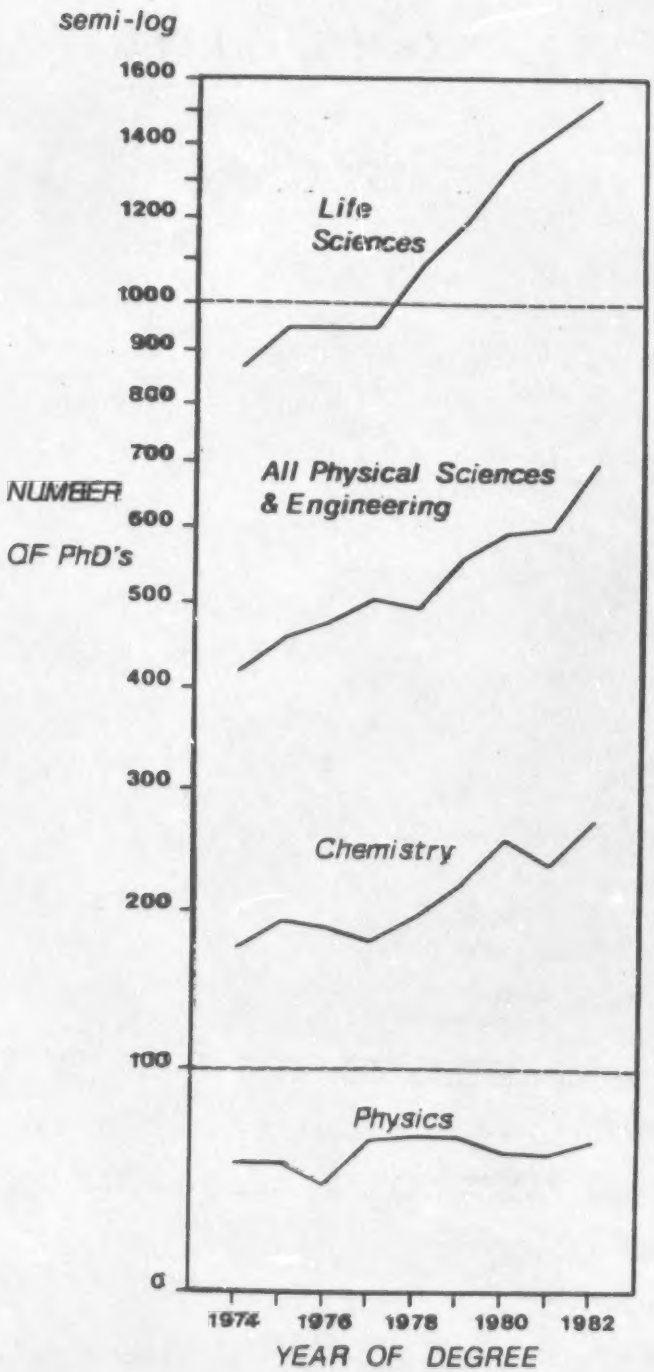

WOMEN IN SCIENCE, 1973-1981
PERCENT WOMEN
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Biology
All Science & Engineering Fields
Math
Chemistry
Earth & Environmental Science
Physics & Astronomy
1973
1975
1977
1979
1981
YEAR
SOURCE: NAS

Chart 5



PhD's AWARDED TO WOMEN BY FIELD AND YEAR OF PhD.

Chart 6

PHYSICS PhD PRODUCTION, 1981-1991.

ACADEMIC YEAR REPORTED	NUMBER OF PhD'S	% US CITIZENS
1980-81	927	74
1981-82	912	76
1982-83	921	73
PROJECTIONS BASED ON PIPELINE [A]		
1983-84	911	73
1984-85	914	70
1985-86	933	67
1986-87	961	64
1987-88	993	61
1988-89	1028	60
1989-90	1052	60
1990-91	1062	60

[A] THESE SHORT TERM PROJECTIONS ARE BASED ON PROBABLE COMPLETION BASE RATES APPLIED TO PHYSICS STUDENTS CURRENTLY IN THE PIPELINE, I.E. UNDERGRADUATE MAJORS AND GRADUATE STUDENTS IN PHYSICS PROGRAMS IN 1984.

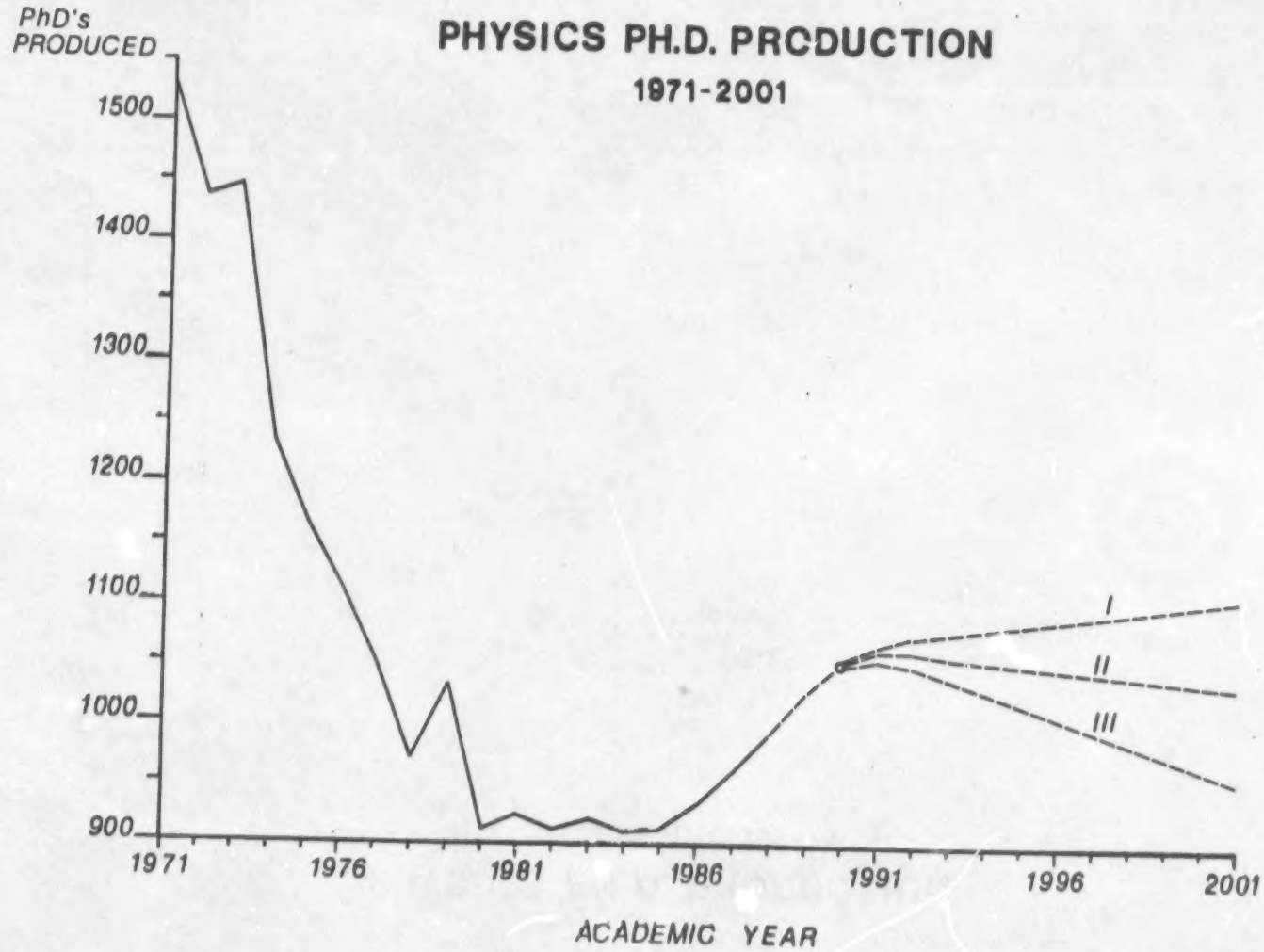

PhD's PRODUCED
PHYSICS PH.D. PRODUCTION
1971-2001
1500
1400
1300
1200
1100
1000
900
I
II
III
1971
1976
1981
1986
1991
1996
2001
ACADEMIC YEAR

Chart 7

43

PHYSICS PH.D. PRODUCTION
BY CITIZENSHIP, 1981-2001.

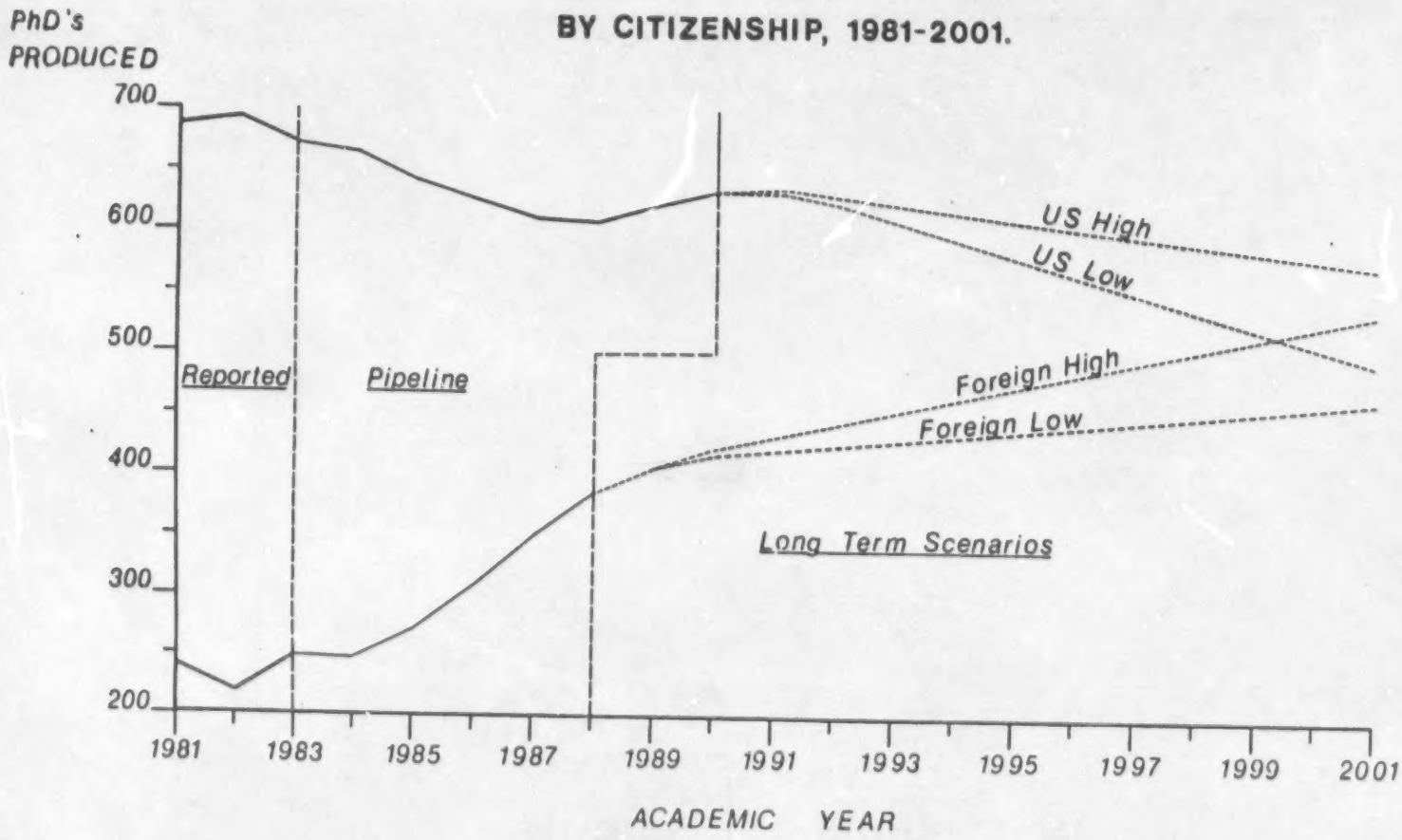


Chart 8

Alan Fechter, head of the Office of Scientific and Engineering Personnel of the National Academy of Sciences, discussed "The Talent Pool for Engineering: Are the Colleges the Only Source?

I am delighted to be able to participate in this joint meeting of the Scientific and Engineering Manpower Commissions. I am also pleased that the Office of Scientific and Engineering Personnel was able to facilitate arrangements for holding this meeting here at the National Academy of Sciences.

My charge today is to examine the talent pool for engineering and to assess the various sources from which this talent is drawn. I recognize that engineering activity requires many talents, including those of support and technical staff, as well as those of engineers. In my remarks today, however, I shall confine my attention only to the engineers. In developing these remarks, I have drawn heavily on material generated by a symposium sponsored jointly by the National Academy of Engineering and OSEP on labor-market conditions for engineers, held in February 1984, and on material generated by the Panel on Infrastructure and Modeling of the Committee on the Education and Utilization of Engineers. I begin my remarks by discussing some labor market and policy implications of the way in which the talent pool is defined. I then examine the evidence on recent and projected future sources of engineering talent. I close with some thoughts on the research and policy implications of this evidence.

I want to stress the importance of sources of supply other than those provided by educational institutions in the form of new graduates. These other sources represent pipelines that are not normally emphasized in labor market analyses; yet, they can be critical in determining whether and how well labor markets will be able to accommodate short-run or unexpected fluctuations in employment demand--particularly in labor markets for skills that require long periods of training. This is especially true in the labor market for engineers, where demand is highly sensitive to the business cycle and to the volatile swings that have been experienced in defense spending, and where new supply flowing from the colleges and universities can not instantaneously accommodate these changes because of the extensive time required for training. The adjustment period can be even longer if market signals are slow in reaching potential engineering graduates and if students do not act on these signals instantaneously.

An important policy implication stemming from the recognition of these other supply sources is that an excess of job openings over new entrants to the labor force does not necessarily imply a shortage of workers. One must delve more deeply and examine whether the quality of the work force deteriorates and/or whether employment costs rise because of factors such as increased search efforts required of employers to fill their vacancies.

Turning to the empirical evidence on whether the colleges are the only source of engineering talent, the answer is a resounding "No". In his paper, prepared for the OSEP-NAE Symposium on Labor Market Conditions, Ronald E. Kutscher, Associate Commissioner, Office of Economic Growth and Employment Projections of the Bureau of Labor Statistics estimates, based on data for 1980, that only 46% of the new entrants to engineering occupations were recent engineering graduates. Other evidence based largely on NSF data for the

1970s supports Kutscher's finding. Annual engineering job openings for the late 1970s are estimated by adding job openings created by employment growth (new demand) to job openings created by turnover, including death and retirement (replacement demand). A lower-bound estimate of new demand is derived from National Science Foundation "composite" of "national" estimates of the engineering work force for the late 1970s. (The estimate of new demand is considered a lower-bound because there are indications that the "composite" estimates probably understated trends for the 1970s.) Based on these data, I estimate that new demand created approximately 40,000 job openings per year. Replacement demand is estimated from a combination of NSF data on occupational mobility for the period 1972-1978 and on BLS data on mortality and retirement. Using these data, I estimate replacement demand to be slightly less than 70,000 per year. Combining new demand with replacement demand produces about 110,000 job openings per year. It is interesting to note that replacement demand in the 1970s was more important than new demand in creating jobs for engineers. Assuming roughly 80 percent of the bachelor's and master's degree recipients and 55 percent of the Ph.D. recipients find jobs in engineering, I estimate that roughly 52,000 or 47 percent of the annual job openings in the 1970s, were filled by newly graduated engineers.

How, you might ask, did the other job openings get filled? The answer is: they were filled by individuals who came from a wide variety of sources, including (1) workers with related skills--e.g., transfers from physics and chemistry and upgrading of technicians; (2) workers with previous engineering experience who left engineering for other fields and who are returning to engineering occupations; (3) workers from foreign countries; and (4) recent graduates with degrees in fields other than engineering, including engineering technologists. These other sources may become an even more important source of supply in the future if demographic trends produce declines in engineering degree production and if the number of job openings increases from the levels that were experienced in the 1970s.

What does the future hold, then? Let me turn again to the recent Symposium on Labor Market Conditions for Engineers for an answer to this question.

Four models of the engineering labor market--those of the American Electronics Association (AEA), the Bureau of Labor Statistics (BLS), the National Science Foundation (NSF), and the American Council on Education's Business-Higher Education (B-HEF)--were examined in depth. On the demand side of the market, the three comprehensive models (BLS, NSF, and B-HEF) were in reasonable agreement in projecting strong growth. (These forecasts were all based on an assumption that there would not be a repeat of the severe economic downturn experienced in the beginning of the 1980s.) Forecasts of annual employment growth for all engineering fields over the next five to six years ranged from about 30,000 to 60,000 or 2.5 to 4.5 percent per year, depending on the assumption made about aggregate economic growth and increases in real defense spending. Growth for electrical/electronics engineers was projected to be slightly higher--ranging from four to five percent. In addition to this employment growth, new hires would be required to replace currently employed engineers who are expected to leave the work force because of death or retirement or who are expected to move to non-engineering jobs. This expected replacement demand far outweighted in importance the

demand generated by expected employment growth and ranged from about 60,000 to 90,000 annually, or from six to nine percent of the work force depending on the model and economic/defense expenditure scenario examined. Thus, the annual number of job openings were projected to range from 90,000 to 150,000 per year during the 1980s, slightly higher than the experience of the 1970s.

The forecasts developed by the AEA were more tightly focused on electrical and computer engineers. These forecasts indicated much stronger growth than those of the other models--annual growth rates of 10 to 16 percent for electrical and computer engineers respectively.

On the supply side of this labor market, the studies forecast that about one-half of the projected job openings would be filled by new graduates. The critical issue confronted by those who attended the symposium was whether the large difference between the projected number of job openings and the projected number of new graduates entering the field was cause for concern or alarm. The answer depended on how the inflow of experienced workers was treated. All but the AEA study addressed this inflow. BLS and NSF concluded that it would be sufficient in numbers to meet projected requirements in most fields. There was uncertainty, however, about the qualitative adequacy of this inflow. The B-HEF study implied, by and large, that this inflow would be inferior in quality to those who were already employed and to the newly graduated engineers. The BLS and NSF studies did not explicitly address the quality issue but acknowledged its importance.

Let me close with some thoughts on research and policy implications of these findings. First, the existence and size of these sources of supply indicates the rich variety of ways in which labor markets can adapt to rapid or unexpected changes in demand. Second, given the relative importance of these "nontraditional" sources of supply in meeting job requirements, except for the NSF data from the National Sample of Experienced Scientists and Engineers, we know amazingly little about their distribution by particular sources and even less about the characteristics of those who constitute this supply. To strengthen our understanding of the dynamics of the engineering labor market, we clearly require more information and analysis of these talent pools. Finally, these findings suggest that we should be cautious in reacting to estimates of engineering shortages that ignore the high degree of elasticity made possible in engineering labor markets by these other sources of supply.

Anthony Carnevale, consulting economist, spoke on continuing education for scientists and engineers.

The demand for retraining will increase incrementally in the future, and will impact most heavily on those who are closest to production. The U.S. labor market includes a great deal of informality in hiring, with job acquisition being about 60% hustle and 40% credential. European labor markets are much more rigid. However, this makes the measurement of our labor market more difficult.

Employers either use on-the-job training or upgrading to fill many of their needs. The U.S. record of job creation over the past decade is better, in part, than it might otherwise have been because of the informality in the system.

Employers take responsibility for much of the training that occurs. In workplace training, productivity, wages etc. often are driven by teamwork, which becomes more important than pre-employment training. Thus, both informal training and education are provided by employers.

To better understand the size and shape of workplace training of a formal type that is carried out by employers, training costs paid by them are $20 to $30 billion per year. It can be inferred that total training probably represents three to five times this figure.

Especially in the technical professions, such training is vital. Workers report learning their job skills in the workplace, and a new study by the Bureau of Labor Statistics says the same thing.

Informal, on-the-job-acquired information is vital to workers for promotion and salary advances. However, we tend to deny this experience to women and minorities. The basic prerequisite for successful labor participation is access into the labor force and to its informal training system.

Thirty to forty percent of all formal training which is provided to workers by employers is carried out at two and four year colleges. Most American industry supports this training across occupations and across industries. Within the formal training supplied by employers is a large spread of information, but a great deal of it is concentrated in technical fields.

Workers need both education and training. The range of offerings is widening. It is necessary to think about how the educational/training system operates, by watching it work. Those who do not understand it will fail to forecast future needs and opportunities, and may mis-inform students and parents who seek such information.

Richard Wilcox summed up the day's presentations, noting that the pipeline analogy is a good one for science and engineering. Leaks in the pipeline are not of concern, since it is important that people working outside of these fields understand something of them and their relationship to other fields. Every citizen needs a good educational base that includes some science and technology, as well as mathematics. Alternate sources, however, both for supply when needed, and for utilization, are vital if we want to damp out the spikes that occur in both supply and demand because of the long educational lead time required for entry into these professions.

We know more about modeling than we use. A recent study by the Center for Strategic and International Studies on scientific and technical manpower sees some emerging problems. They include the need to raise expectations for our students; to raise standards all around; and to look for alternate labor sources.

THE 1984 JOINT MEETING OF THE SCIENTIFIC MANPOWER COMMISSION AND THE ENGINEERING MANPOWER COMMISSION

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